THE GREAT SOIL GROUPS OF THE WORLD AND THEIR DEVELOPMENT

BY

PROF. DR. K. D. GLINKA
Director of the Agricultural Institute, Leningrad

Translated from the German
BY
C. F. MARBUT
U. S. Department of Agriculture

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TRANSLATOR'S PREFACE

The great world of Russian soil literature is almost wholly unexplored by scientific men in America. This is especially true of the large and rapidly increasing number of men engaged in the work of the various agricultural institutions the country over. The language is not read, even with difficulty by one per-cent of the scientific men in this country. Up to the appearance of this book early in 1914 no comprehensive summary of this work had been published in a language available to American readers and the outbreak of the great war prevented its importation into this country for many years.

Even if conditions since its publication had been favorable to its importation it could not have reached as wide a circulation as it deserves because the languages even of Western continental Europe are not sufficiently familiar to a great number of the students and others engaged in agricultural work in this country to enable them to read them with facility.

The soil has been looked upon by scientific men in America and Western Europe largely from one or the other of two points of view. It has been considered either as a medium in which plants grow on the one hand, or merely as a geological formation with slight modification of no great importance on the other. The representatives of the first group have confined themselves in their investigations to questions that concern the getting of immediate results in crop yields. Those of the second group have given the subject very little attention, a mere passing notice.

The existence of Russia as an empire with tremendous geographic extent stretching over a large part of the greatest continuous land area of the globe, and the presence in that country of the great belt of strikingly characteristic Tschernosem soils were the two main factors in the development of the first and only comprehensive theory of soil genesis, aside from that of the genesis of soil material, that has yet been worked out. The Tschernosem attracted attention to the soil because of its striking characteristics and the equally striking region in which it occurs. The tremendous extent of the country gave Russian investigators the opportunity enjoyed by those of no other single country in the world: that of studying the characteristics of soils within their own country in regions of widely different climatic, geologic, topographic and biologic conditions. The conditions presented in but one other country, the United States, approach them but the two factors of agricultural history and our agricultural individualism worked powerfully to prevent the development of such results in this country.

The fact that the soils of our own country are so much like those found in Russia and Siberia makes the results of Russian soil investigation peculiarly interesting to American investigators. The book however is more than interesting. It is destined to have an important influence on the course of soil investigation in this country, not because all its conclusions are correct or all the principles developed are immediately applicable to conditions here, but partly because of the thought stimulation always effected by the presentation of new points of view and partly also because of its suggestiveness as to methods and the broadening of conceptions by the presentation of the geographic and climatic points of view.

The field investigation of soils in this country began with the study of the soil in detail. No such work had ever been undertaken in any country. There were no traditions to guide us or to offer suggestions. Even the results of the Russian work, broader in its general viewpoint though it is, were not available because of the language in which they were preserved. Although therefore our work has dealt mainly with details they have been details of geography in considerable measure while the broader geographic conceptions of the Russians have been accompanied with ideas as to details of soil character that may with great profit be brought to the attention of American investigators. In the more detailed study of the soil profile, the clearer recognition of the nature of soil horizons, soil structures, soil colors and in the relation of soil chemistry to the processes of soil development in Nature, this book will be of great suggestive value to American investigators.

C. F. Marbut

AUTHOR'S PREFACE

The following work covers a part of my Russian lectures. In order to place before the West European reader those parts of the science of soils, or Pedology, which are of special interest to Russian investigators, and with the working out of which they have been mainly concerned, it became necessary to translate them out in German. Russian soil literature is not unknown in either Europe or America but only a few out of the very great number of works are known and of these practically nothing but abstracts. In the following pages therefore I attempt to sum up all observations which have been made by Russian investigators in the field of soil genesis and the geography of soil types as well as the conclusions they have drawn from them.

To be sure, in the consideration of the problems of the genesis and geography of soil types, I do not rest content merely with Russian observations but make use of West European and American literature. Some of the great soil groups have not been studied by Russian investigators because the opportunity to study them in the fatherland has not been presented to them. This is true of Laterites and the soils of subtropical latitudes. Russian scientific literature is especially rich however in the results of chemical, physical, morphological and geographic studies of the soils of the forested regions of northern Europe, the Steppes of Eastern Europe and the semi-arid regions of southeastern Europe and Western Asia. Nowhere else is there such a wealth of material.

I do not undertake, in this work to present any special discussion of any of the fundamental physical or chemical principles involved in soil science. For example I do not discuss the formation and characteristics of humus, or the processes of weathering since West European readers may find abundant material of this kind in their own literature.

In order to make clear my own point of view as to the justification for the existence of Soil Science, and in order also to bring out those ideas which have served as guides to Russian investigators in both field and laboratory, I consider it advisable to begin this book with a full introduction.

My warmest thanks are due to Professor Dr. H. Stremme of Berlin who undertook the laborious work, in single minded devotion to science and without profit to himself, of improving my imperfect German and who has extended to me at all times the most valuable assistance and the wisest counsel.

K. Glinka.

SUBJECT MATTER AND AIMS OF PEDOLOGY

The origin of soil science or Pedology, like many other sciences, is to be sought among the ancients. In the seventh century before Christ soil descriptions were already in existence.[1] Man doubtless began to accumulate the facts of observation about the soil from the time he began to learn the art of using it to produce crops. All sciences seem to have had similar beginnings. Herbert Spencer developed Humbolt's idea of the importance of use as the great underlying cause of the development of all science; that in its first stages of development it followed practical lines because of the struggle by man toward the utilization of Nature. Another force however much more powerful than this appears almost simultaneously with it. It is the struggle of our nature for the acquisition of abstract knowledge or for the discovery of the laws of phenomena. Gradually the latter becomes the more powerful, and if at the present time we are able to point to continuous progress in many branches of science we should recognize that it is due primarily not to those who seek scientific knowledge merely for use but to those who have attempted to formulate the laws of Nature. A careful study of Pedology discloses the fact that in this science also the same two phases of development can be traced, marching in part, side by side and in part following one after the other. The first generalizations which we find in the works of ancient writers like Cato, Varro and Columella, deal with the utilization of the soil. Columella sought to determine the quality of the soil by determining experimentally the sweetness and fatness of plants growing it. Cato classified soils not on the basis of their characteristics but on their varying capacities for the production of certain plants.

Scientific curiosity concerning the characteristics of the soil did not manifest itself earlier than the beginning of the nineteenth century but even at its close investigators were not agreed on a definition of what knowledge of the soil is without practical value and what has such value. They do not attempt to determine either the field or the object of Pedology.

Only a few years ago Dafert[2] called attention to the fact that pedological text books having the same title, differ widely in the subject matter treated. It has seemed to me worth while therefore to begin this book with a brief discussion of the fundamental questions with which the science deals and to inquire into the question of its right to recognition as an independent science, distinct from all others. Is it a science with an object of research all its own, distinct from that of all other sciences and are the methods of research different from those applicable to other sciences? As a preliminary to the solution of these questions a definition of the term soil must be agreed upon. When we examine the work of

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1 Jariloff, The First Pedolog of Ancient Times. "Pedologie" 1901 No. 3 (Russian).
2 F. W. Dafert, Ueber das Wesen der Bodenkunde. Landwirtschaftliche Jahrbücher 15, S. 243.

various investigators we see that long ago many of them attempted to give definite expression to their ideas of what a soil is. It would lead us entirely too far to attempt to bring forward all the definitions of the term which have, from time to time, been given.[3] I will content myself with a very few.

In 1837 Karl Sprengel designated the soil as a comminuted and changed mass of material derived from minerals, containing the decomposition products of plants and animals.[4]

In 1855 Friederich Fallou[5] defined the soil as the product of weathering, which gnaws into the hard crust of the earth like teeth and gradually destroys its solidity.

In 1877 G. Berendt[1] defined the soil as the weathered hull or shell of the existing earth's surface which comes into contact with the air.

Finally Dokutschajeff[2] in 1886 defined the soil as the layers of material lying on the surface of the earth or near it which have been changed by natural processes under the influence of water, air and living and dead organic matter.

At first glance these definitions seem to be alike. All agree that the soil is the surface layer or surface portion of the earth's crust which has been modified by the processes of weathering. If, however, we make ourselves familiar with the work of these investigators as a whole we can readily see that their ideas are not at all identical. The most essential difference lies in the fact that some of them designate the soil as the product of weathering in place only while others consider every accumulation of the products of weathering a soil regardless of the process by which it has been transported since being weathered,

In addition to the lack of uniformity of ideas as to what the soil is there has been a further lack of uniformity as to what constitutes the criteria for the establishment of the bottom of the soil layer. A careful investigation of soils shows that the upper few inches, in which the earlier investigators were accustomed to

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3 A. Jariloff, Pedology As An Independent Science of Soils. Part I (453-473) Jurjeff 1904 (Russian).

4 K. Sprengel, Die Bodenkunde oder Lehre vom Boden nebst einer vollständigen Anleitung zur chemischen Analyse der Ackererde. Leipzig, 1837.

5 F. A. Fallou, Die Ackererde des Königreichs Sachsen und der angrenzenden Gegend. Leipzig, 1855.

1 G. Berendt, Die Umgebung von Berlin. Abhandlungen zur geologischen Spezialkarte von Preuszen. 2, Heft. 3.

2 Dokutschajeff, Data for The Valuation of The Soil of Nishny-Novgorod, I, 1886, (Russian).

look for the accumulation of organic matter, is not the only place in which humus substances are found. We shall see that, as a consequence of certain processes, a deeper lying humus layer, less thick and less noticeable than that on the surface is often present. Such a layer has formed in the soils of the forested zone of European and Asiatic Russia. Investigations of the Podsol soils of Northern Russia have shown also that in certain sandy Podsols which overlie bowlder clay at a depth of 3 to 5 feet, the gray podsolized horizon lies just above the clay[1] rather than in the upper part of the soil where it usually occurs. In the Tschernosem[2] zone and in soils developed under conditions of insufficient moisture, a segregation of various salts, including lime carbonate, takes place at considerable depths according to various observers, such as Richthofen, Hilgard, Tanfilieff and others. The mere mention of these facts is sufficient to show that the processes of soil making penetrate to considerable depths into the earth's crust, a fact that is evident to the eye of every careful observer.

If we define the soil as the product of weathering it is evident that we must designate as soil in the wider sense all that part of the earth's crustal layer in which the effects of the weathering process can be recognized.

Van Hise[3] separates the metamorphosed part of the earth's crust into two zones:- the upper is the zone of Katamorphism, the lower the zone of Anamorphism. The first zone is further divided into (1) the zone of weathering whose lower boundary is the level of ground water and (2) the zone of cementation. The zone of weathering of Van Hise is therefore the soil in the wider sense. Cornu[4] who differentiates between surface weathering and secular weathering presents his conclusions somewhat differently from those of Van Hise about as follows: "If we assume that atmospheric water, which has already given up to the upper part of the soil the greater part of its content of carbonic acid and oxygen, percalates downward along the capillaries into the rocks, the continued operation of this process through centuries will form products which will have a composition similar to that of the gels formed in the zone of weathering. These bodies are crystalloids. The geologist observes here the same thing that the chemist observes in his laboratory investigations: i.e. whenever a constant environment is maintained; a constant pressure, constant temperature etc. these crystalloids originate, but whenever these conditions change rapidly, gels will be developed." The "zone of secular weathering"

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1 K. Glinka, Materialen zur Wertschätzung der Boden des Gouvernments Pskow, District Noworshew, S. 14.

2 Bogostowski, Von einigen Verwellerungserscheinungen in den Regionen des russischen Flochlandes. Bulletin du Comité geologique de St Petersbourg, 18, 1899.

3 Charles R. Van Hise; a Treatise on Metamorphism. Monograph 47, U. S. Geol. Survey, Washington, D. C.

4 F. Cornu comptes rendus de la premiere conference internationale agrogeologique. Budapest 1909, S. 125.

of Cornu seems to be equivalent to the zone of cementation of Van Hise. While Van Hise divides the zone of weathering from the zone of cementation at the ground water level, Cornu does not do so.

To all these definitions it is necessary to add that the product of weathering which has been carried from the place where it was formed and deposited in some other place is not soil so long as its external and internal characteristics have not been modified by soil making processes acting upon it under the conditions prevailing in its new locality.

The above statements show us that the soil is a product of the operation of natural forces on a definite portion of the earth's crust. As we shall see later a soil possesses a series of especially characteristic features. We may investigate the soil without interesting ourselves in its relation to man or his agricultural activity. In this respect it is an object of investigation just as are plants, minerals or rocks. As in the case of the latter we do not content ourselves merely with the description of external and internal characteristics but strive to interpret life processes, if one may be allowed to speak in that way of inanimate objects, so also may we seek to treat of the soil. We shall learn to understand the laws of its origin, development and decay; why we find in one place one soil and in another place another soil. We shall determine those special characteristics which differentiate the soil from rocks which constitute the field of the petrographer; why it is advisable to designate it specially from the other surface formations of the earth's crust and why a special science is necessary for its investigation. These are the questions which we must answer fully.

In beginning therefore I have started with the definitions already cited following with a statement of the genetic connection of the processes of weathering with the soil.

There are few places on the land surface of the globe where, as Johannes Walter[1] remarks, the processes of weathering take place under the influence of the atmospheric forces exclusively. In a theoretical way the weathering processes may be subdivided and separately discussed by discussing separately the chemical work of the atmosphere or of water, the mechanical work of water or the mechanical work of changing temperature and other processes in a similar way. When we look at the matter from the standpoint of nature we must think of weathering as the total product of a series of forces. There are complicated physico-chemical changes which take place in every kind of formation on the earth's surface, exposed to the influences of the atmospheric forces on one hand and to the life processes and products on the other.

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1 J. Walther, Einleitung in die Geologie als historische Wissenschaft, 1893-94, Abt. III, S. 554.

The external forces are dependent, first of all upon the general source of energy, the sun. The warming and cooling brought about by insolation and radiation, the movement of the atmosphere, its precipitation as well as the intensity of its chemical activity are phenomena, all of which are intimately related to the activity of the sun. It dominates also the life existing on the earth's surface. It conditions the distribution of animal and plant groups, influences the stage of development of individual representatives of the plant and animal kingdom, determines their density of occurrence, and brings into existence, with the help of other factors, definite types of plant and animal formation. The activity of the sun, however, is not equal in its intensity on all parts of the earth's surface. It warms and lights the tropics intensely, the temperate zones much less and least of all the polar regions.

These references will suffice to enable us to draw the conclusion that the soils of the earth's surface, being a product of all these forces, could not all be alike over the whole area even if the earth's crust were everywhere composed of the same kind of rock, and that regions with the same conditions of weathering must have soils of the same general type.

This logical conclusion, which at the present time is fully intelligible, could be drawn only after investigators had acquired a clear conception of the term soil. If the soil is looked upon merely as an ordinary geological formation, as any sort of a surface deposit, as a crop producer or as a nourishing layer for plants, we have no uniform basis or series of bases on which to establish any systematic scheme of grouping. That there are many kinds of soil is a fact well known by everyone who has studied them. They have been classified in actual practice on the basis of the most divergent principles. Soils developed from diorites, granites, basalts and trachytes cannot be the same in all their features because of the wide differences between their parent rocks. They have been differentiated therefore as granite soils, diorite soils, basalt soils, etc. They have been grouped also as light and heavy, compact and friable, clayey and loamy, sandy loamy and sandy soils. On the basis of the chemical character of specially noticeable constituents they are grouped as lime, marl, sulphate soils, etc.

Such terminology is based on petrographic, mechanical or chemical characteristics, but it is not possible to base the laws of distribution, or of differentiation, other than that of the rocks themselves, on such criteria. The distribution of such soil units also would be the same as that of the rocks from which derived and would be petrographic rather than pedologic. Not until soil development had been studied in a broad way and its relation to factors whose distribution is controlled by general rather than local laws, such as climatic factors, had been determined was it possible to develop a geography of soil types with a basis of classification of any importance in pedology. To base soil type definition and differentiation on climate is now recognized not only as

logical but as based on comparative studies of soils in all parts of the world.

The first promulgation of such ideas appeared in the late seventies of the 19th century.[1] Soil investigations carried out over wide areas in European Russia showed that every type[2] of soil covering large areas of country is characterized by a profile typical of that type only.[3] The Podsol soils of the northern part of the country, the Tschernozems of the central part, the Kastanienfarbige (chestnut colored) and Brown soils of the south show in their profile and other characteristics that they are widely differing bodies. They are not only diverse in profile and other characteristics, but also in distribution. The regularity of the latter is so striking that the existence of a law controlling it is strongly suggested. Such regularity cannot be explained from either the geological or the botanical standpoint for it can be shown that often widely different soils are developed from the same kind of rock, and on the other hand that the same soil type, as for example, the Tschernozem, can be developed from widely different parent rocks such as loess, bowlder clay, Jurassic clay and granite. Where certain specific forms of plants occur in intimate association with a given soil such relation is doubtless dependent upon the climatic conditions obtaining in the area. On that account we must take into consideration a complex series of factors which have acted together to produce soils of the earth yet, for most soils at least, the climatic factor is the most important of the group. This same conclusion has been reached as a result of the investigation of the soils of tropical and subtropical latitudes of Central Asia.[1] Laterite, the characteristic weathered product of tropical lands, played the important role in this question. It lies on widely diverse rocks but everywhere has the same or similar typical characteristics. Its wide distribution and uniform characteristics constitute a strong presumption in favor of a control over its development by characteristic conditions whose distribution is equally

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1 Richthofen. In the work of Richthofen the influence of the work of Fallou is noticeable. The latter developed the idea of the divergence of the soil from its parent rock though he did not explain the reason for it. On this account both Fallou and Richthofen use soil and mechanical deposite interchangeably. In the chapter on Soil Classification this will be fully brought out.

2 The word <u>type</u> referring to soil is used throughout this work as a broad group of soils, not as a designation of an individual soil unit as used in the reports of the U.S. Soil Survey. (C.F.M.)

3 Dokutschajeff, Kartography of Russian Soils, 1879, and also Work of The Naturalists' Society of St. Petersburg, X, XI, XII and "Russian Tschernosem" (Russian) 1883.

1 F. von Richthofen, China 1-2, 1877-1882. Führer für Forschungsreisende, 1886.

wide. A search for such force fails to reveal anything but tropical climate. The study of the soil geography of North America[2] has in a no less convincing way enforced the recognition of the close relationship between the soil and climatic conditions. The study of the soils of South America[3] and North Africa[4] show the same relationship.

The importance of climate can be shown in still other ways. As was stated above, weathering is the result not only of the forces of the atmosphere but also of biological forces. When man became convinced that the decomposition of organic remains on the earth's surface and in the soil took place mainly as a consequence of the life processes of low organisms which lived in countless numbers in water, air and earth, the question immediately arose as to the conditions under which these organisms live and work in the soil. Investigation showed that the intensity and character of their activity was dependent, in the first place, on temperature and moisture.[1]

If the decomposition of organic matter takes place rapidly, little humus is formed in the soil. If however, the weathering processes act slowly, a larger amount of humus will accumulate. Soils rich in humus, however, differ widely in character since the accumulation of humus can take place both in the presence of an excess of moisture and also under conditions of deficient moisture. The character of the decomposition of the organic matter determines also the character of the humus that is produced by it. Organic matter weathered in the presence of an excess of moisture will contain the smallest percentage of oxidized compounds while that weathered under conditions of deficient moisture will contain the largest percentage of such compounds. In the latter case the humus will be saturated with ash constituents, in the former, it will not be so saturated. In soils as everywhere else in Nature the products of extreme conditions do not constitute all the possibilities. Products of intermediate conditions are usually present. The fact that the humus compounds of different soils react differently to water is an evidence of the diversity of characteristics of this material. The chemical character of the humus exercises a strong influence on the decomposition of the primary soil minerals as well as on the formation of those secondary products resulting from the complex reactions between the humus and the various products of decomposition.[1] The latter are subjected to the influence of climatic conditions and they form the characteristic constituents of the soil aside from the primary minerals.

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2 E. Hilyard, Wollnys Forschungen, 16 H. 1 u. 2, S. 82-172.

3 Wohltmann, Handbuch der Tropischen Agrikultur, 1892,--Sapper, Petermann's mitteilungen, Ergänzungsheft No. 127, 1899.

4 Blanckenhorn. Zeitschr. d. deutsch. geolog. Gesellsch., 53, 1902.

1 Wollny, Die Zersetzung der organischen Stoff und die Humusbildung 1897.

1 K. Glinka, Investigations in the Realm of the Weathering Processes. Work of the Imperial Society of Naturalists at St. Petersburg T. XXIV, No. 5, 1906 (Russian with German resume). P. Treitz.

The above stated briefly, outlines the history of the accumulation of facts and the development of the principles which constitute the solid foundation of one of the fundamental laws of Pedology: The law of the development of soil types on the earth's surface under the influence of climate.

The soil is essentially different from the other rocks of the earth's crust in the following respects:- It is regularly distributed over the earth's surface, the other rocks are not. It has a characteristic complex of new mineralogical and organo-mineralogical compounds, a complex which differentiates it more or less from those compounds present in the other constituents of the earth's crust.[2]

Soils have a characteristic layered arrangement of their parts. This feature known as the soil profile gives a characteristic expression because of the special conditions under which it was developed.

The soil has a very close connection with the organic life of the earth and exercises a reciprocating influence on it. Although the soil is itself one of the rock formations of the earth's crust it possesses characteristics so peculiarly and exclusively its own that the methods by which it is investigated must necessarily differ from those adapted to petrographic or stratigraphic investigation.

The stratigraphic-palaeontological method is not at all adapted to it and the petrographic method does not suffice. The character of the object itself and the methods necessary in its investigation differentiate it from other sciences and make of it a new science, constituting a special branch of Geography or Earth science. The isolation of such a branch is not new in the history of science. Geology first developed as such and later broke up into petrography, stratigraphy, palaeontology, etc., all of which seek the same end:- a full and harmonious picture of the crust of the earth and its development. Such disintegration, if such it may be called, promotes the progress of science. Although a Leonardo da Vinci could work in the field of physics, astronomy, geology, botany and anatomy, such is not possible at present even for the greatest talents. The necessity for specializing grows from year to year yet we must be careful not to allow the boundaries which separate us from other sciences to be converted into unscalable walls depriving us of the possibility of obtaining world encompassing views.

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1 Cont'd.
Was ist die Verwitterung? Comptes rendus de la première conference internationale agregeologique. Budapesth 1909. Cornu, Die heutige Verwitterungslehre im Lichte der Kolloidchemie. Neue Freie Presse, 1909, 2 März.

2 Wernadski, Notes on The History of Pedology, "The Scientific Word" 1904 (Russian).

The Investigation of Soils in the Field and Laboratory

As stated above the soil is marked by characteristic external features which must be carefully investigated in order that they may serve as a basis for the identification of soil types in the field. It should be remembered that we designate as soil the products of weathering which remain in the place where weathered. It must carry the impression of all inner and outer forces which have taken part in its formation. In the morphology of the soil type the climatic conditions of the locality, the combined effect of moisture and heat, the essential features of vegetation and the character of the parent rock all find expression. Each of these factors constitutes a part of the soil forming processes. Above all the soil will be recognized through the presence of definite structure characteristics, which vary with the variation of the various soil forming factors. By the term profile is designated everything that is presented to the eye of the observer in a vertical cut through the soil exposing its various horizons. This picture, often very irregular and complicated, requires the exercise of special care in its observation and description. The upper layer is predominently more or less dark colored through the presence of organic remains. In depth, however, the color becomes either lighter or darker and the transition from the dark layer colored by organic matter to a colorless or differently colored layer is usually gradual. The color boundary between two adjacent layers can rarely be located as an exact line.[1] Beneath the humus layers one often sees evidence of the change to the parent rock. It may be whitish in color or blue, green or brown or other spots and seams may occur in or traverse it. Often continuous horizons have been formed which are sharply differentiated from the surface layers in their characteristics. In other cases various substances such as sulphates, carbonates or oxides of iron, aluminum and manganese with their hydrated forms have separated out as distinct and relatively pure bodies at various depths beneath the surface. Again a lower, sometimes discontinuous humus layer, often somewhat faintly expressed, appears at varying depths below the surface. The distribution in the soil profile of the horizons carrying spots and tubes and variously shaped bodies of distinct colors is not accidental for it has a very close relation to the processes by which the soil has been formed:- With the accessibility of air and moisture to the soil or the facilities for their passage through it, with the activity of roots and micro-organisms and with the life processes of the soil fauna. In short: Soil structure and morphology is, so to speak, a reflection of those complicated processes which have taken place and are still taking place in the soil.

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[1] Because of this fact Russian investigators use the word Horizon rather than stratum to designate the various layers in the soil profile.

Among the most important features which characterize a virgin soil or one that has lain for a long time uncultivated is the structure which characterizes the surface layer. For example, the surface horizon of the virgin Tschernosem is characterized by a pea-like structure, while the gray forest loam a short distance below the surface is characterized by the so-called nut structure. Both belong to the group of granular structures. The lamellated or platy structure which often appears in the Podsol soils and in the upper horizon of certain types of alkali soils is another and easily recognized variety. A third type appears in the columnar or prismatic structure which characterizes the deeper layer of the alkali soils just referred to. In laterites a certain honeycomb or sponge-like structure is characteristic. Certain horizons are porous or full of cell-like openings. Such structures follow the lamellar or structureless horizons.

The color of the soil is a characteristic no less important than its structure, when it is not due to the color of the parent rock. In the surface layer, the color is often, if not usually, determined by the presence of organic matter, though it is often due more to the presence of iron or manganese oxide or to other metallic salts. Organic matter imparts to the soil black, brown, gray, or white color, compounds of iron (hydroxides, silicates, ferric and ferrous iron oxides and their salts) give all possible colors, and the oxide of manganese gives a black (often glistening) and brown color.

The most important morphological characteristics of the soil, especially the structure and color of the soil types must be studied in their natural environment. For this purpose the investigator digs as deep into the soil as the influence of the soil making processes has penetrated. Since this depth is very variable, the mean depth cannot be determined except by direct observation by boring or digging.

Natural exposures, such as those along gullies and stream channels can be utilized as aids to soil study but artificial exposures, such as dug wells, quarries, clay pits and railway cuts are better, when fresh. It may be remarked in this place that the investigator cannot always content himself with the depth in which the soil making processes can be seen with the simple unaided eye, and he must not forget that traces of their action manifest themselves in various ways down to the ground water level, for on the one hand the atmospheric moisture by gravity or capillarity penetrates to the ground water surface[1] while on the other the ground water may rise to the surface and in both cases will act on the soil.

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[1] Rene' d'Andrimont, Les principes de la circulation de l'eau dans les terrains meubles et leur application. Verhandlung der Zweiten internationalen Agrogeologen-konferenz. Stockholm, 1911.

After the investigator has made an excavation in the soil to the proper depth he selects one of its walls which is sufficiently and uniformly lighted and makes it vertical. Uniformity of illumination is necessary since the soil in unequal illumination, even when it is alike, will show different color shades. Direct sunshine should be avoided. The vertical walls, in order to allow all details of the exposure to come to light, should be cleaned carefully with the spade. The powdered soil particles which have been formed in the preparation of the vertical wall should be carefully blown away, so that they do not cover the profile. The investigator then begins his measurements with tape or rule. The thickness of every horizon which is differentiated by any characteristic whatever, such as color or structure, from adjacent horizons should be measured. The boundary of the horizon is not an exact one as a rule. Its thickness therefore is variable and the boundaries of the gradations should be determined. If bodies of salts have formed in the soil, the depth at which they make their first appearance must be noted. Among the salts one finds lime carbonate almost invariably. The depth at which it appears in the soil can be determined through effervescence with hydrochloric acid.

All measurements should be noted as well as the characteristics of the several horizons in color, structure, texture (such as sandy, sandy loam, loam, etc.); acculumations of salts whether they be in the form of irregular spots, tubes, continuous layers or concretions, occurrences of other compounds such as hydrated oxide of iron and alumina or oxide of manganese; animal burrows, their size shape and color of the filling material; the relative moisture content of the several horizons and, in general every feature of the soil which can be noted in the vertical wall. At the same time the investigator should draw the profile in his note book and then collect samples.

A block of soil of considerable size can be secured by using the Rispoloshenski apparatus. This consists of an open iron box with sharp edges. Its length, breadth and depth can be made of any size but it is convenient to work with the narrow, shallow and short ones, about 4 to 5 centimeters deep and 20 centimeters wide.

It would be advisable to take samples of the various depths, in their order from the surface downward with the same box, accumulating in this way a sample of the whole profile. To take a sample the sharp edges of the box are placed against the vertical wall of the excavation; against the opposite wall is placed a wooden board and a screw is adjusted with one end against the box and the other against the board. By turning the screw the edges of the box are forced into the soil. To prevent an indentation of the bottom of the box by the pressure of the screw a board should be placed across it. When the box, however large it may be, has been pressed into the soil, a sharp edged cover is driven into the soil against the cutting edges of the box, thus cutting off the soil so that the box is filled with a block of the undisturbed soil. The upper end of the lid is thickened so that it may be hammered into position. The soil block thus secured is taken from the box and placed in a wooden box of the same size fitted with a lid.

With some experience, however, as is shown in Figure 2, a monolithic sample may be taken without the use of the Rispoleshenski apparatus. Samples taken in this way in the most distant parts of Asiatic Russia (the Amur region, Yakutsk region) have been received in excellent condition in our laboratory at Woronesh.

Since the taking of the monolithic sample and its transportation are difficult in many ways, separate samples of each horizon are often taken and in doing so great care should be exercised in order not to destroy the soil structure. Typical parts of the several horizons are selected for sampling. The samples should be wrapped in soft but thick wrapping paper. The moist samples should be packed up only after they have been dried in the air of a dry room, each sample numbered to correspond to the number of the profile drawn in the note book and lettered in accordance with the lettering of the horizons in the field profile.

In recent investigations the soil horizons are designated as follows: The letter A is used to designate the eluvial horizon, that is to say, the horizon from which, in the processes of soil formation either by chemical or mechanical means more or less material has been removed. With the letter B the illuvial horizon is usually designated. This is the horizon into which material has been carried, chemically or mechanically. The parent rock beneath is designated by the letter C.

Since it often happens that the horizons are not uniform in their morphological features throughout, the letters A_1 B_1, A_2 B_2 are used to designate different parts of the modified horizons. In soil investigation the use of boring apparatus is not recommended, since the exact determination of the morphology of the soil profile is impossible by this means.

If a complete investigation of the soils of a region is desired, the work should be carried on in the following way:

The investigator makes himself familiar first of all with the general scheme of soil differentiation in the region to be covered. For this purpose he crosses it at least twice in directions at right angles to each other. One of the directions must be chosen so that it will cut across the main valleys of the region or will cross at right angles the strike of the rocks. With every change of relief, parent rock, plant formation, change in color, the investigator must study the formation and morphological characteristics of the soil.

In this way it is possible for the investigator to determine the main soil types of the area as well as establish the main facts regarding their distribution. After this preliminary work is done he can then lay his plans for a more systematic and detailed investigation.

A full and thorough description of the soil profiles must be made in the field note book but in addition to that the investigator must describe: (1) The geographic position of the locality in which the profile was studied (it is always desirable to locate this place with the greatest possible accuracy on the map or by means of actual surveys), (2) The relief of the locality (slope, elevation, etc.) (3) The character of the plant cover (it is desirable also to make a collection of the typical local native plants), (4) The local name of the soil. For each of the soil types a monolithic sample should be taken at the close of the work, preferably after not only the most important varieties of soil have been identified but also the places where each is most typically developed have been located. Other soil samples, in smaller quantities, may be taken, either for use in laboratory investigations or for a fuller and more complete investigation of certain morphological features. For the determination of the color of the surface horizon and for comparing the shades of color of the various soil types and varieties with each other such additional samples are of special importance. During the progress of the field work, where the soil types must often be studied under various conditions of moisture it is difficult, under varying illumination (morning, noon and evening) to distinguish the various color shades and to compare them with each other. In the laboratory where one has the samples under approximately uniform moisture conditions and uniform illumination, the determination of the shade of color is such simpler and easier. The surprising uniformity in color of samples of the same type taken from widely separated localities is shown by the following incident: At the International Pedological Congress at Budapest I compared the color of the chestnut colored soils of Hungary with that of the same soils from Roumania and from the Akmolinsk and Turgai region of Asiatic Russia. The color was so nearly identical that many of the scientists present thought that all the samples had come from the same excavation. This impression was strengthened by the identity of all other morphological characteristics.

After the investigation of the morphological characteristics has been completed the investigator selects the typical sample for investigation in the laboratory, consisting of the determination of the petrographic physical and chemical characteristics and the chemical composition. The main object sought is the discovery of the processes which have led to the formation of the various soil types. In the processes of soil formation a transfer of various substances from one horizon to another usually takes place, partly by chemical action and partly in a mechanical way. In the laboratory it is necessary to determine what the one horizon has lost by these processes as well as what the other has gained. In this part of the work attention must not be confined exclusively to the surface horizon. On the other hand all the soil horizons which could be identified in the field must be investigated in detail and their characteristics compared with those of the parent rock.

In conclusion I must dwell for a moment on the very important matter of the changes which take place in the soil under the influence of seasonal variations of climate. On the influence of these changes on the soil solution and soil colloids we have some rather fragmentary information. Of the soil solution we know that its composition changes with the seasons. For alkali soils this has been established by the Hungarian investigators.[1] With colloids the change from the gel to the sol form is dependent upon the temperature and the presence of electrolytes in solution.[2] All the data we have is interesting though it consists merely of isolated and disconnected facts.

The fact that soil investigators up to the present time have studied mainly the static condition of the soil can be easily understood. Before the methods for the investigation of soil changes, of its life so to speak, can be worked out man must know soil geography and must know how to differentiate soil types and varieties. We possess already, in this field, a great deal of information and perhaps the time has come for the study of the life processes of the soil.

That Pedology needs continuous systematically organized observation, no less than does meteorology has been discussed in another work.[1] Not only must the changes of temperature and moisture in the various horizons be studied but the changes in the concentration and composition of the solutions and pseudo solutions as well as all the phenomena manifesting themselves in the soil must be observed.

Soil Classification

Before we describe in detail the soil types and their varieties let us make a brief survey of the field as a whole. The problem of soil classification is difficult and complicated but we cannot disregard a systematic arrangement of our facts merely because up to the present time they are very incomplete. As a matter of fact all systems of classification, those here proposed as well as all others, are provisory. They must change continually with increasing knowledge.

As was stated by Ampere long ago, a complete scientific classification would be possible only if men could know all about the objects to be classified. Therefore none of the existing classifications of natural history objects is to be regarded as complete, though such classifications are indispensible.

The logical relation of the purposes of a scheme of classification to the fundamental basis of its structure is stated by John Stuart Mill as follows:

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1 P. Treitz
2 See the chapter on "Alkali Soils".
1 K. Glinka, Text Book on Soils, 1908, (Russian)

"The fundamental purpose of a classification is accomplished if it causes one to think of the facts in such groups and of the groups in such successive order that one can call to mind most quickly the fundamental facts on which its laws are based and can retain them at the same time with the least difficulty.

"In order to accomplish the purpose of a scientific classification it is necessary to group the facts in such a way as to express the greatest possible number of general properties, properties of greater importance in the range of their applicability than any that could be expressed in any other grouping of the same objects. For this reason the objects must be so classified that the characteristics which constitute the basis of the classification constitute, at the same time, the causes or at least the evidences of many other characteristics. Of the latter those that are of fundamental importance and capable of attracting attention must be selected. The characteristics which serve as bases of the main class groups can rarely be used as such if the groups be broken up. In most cases one must select, instead of ultimate causes, only important consequences which are themselves the forerunners of other consequences or even the causes of the same. A classification built up in this manner is a scientific or philosophical one."

We shall now see how and to what extent the various types of soil classification meet these requirements. We will take up for consideration representative classifications only because the consideration of all classifications would consume too much time and take up too much space. We shall concern ourselves therefore with the classifications of Thaer, Fallou, Knop, Baron Von Richthofen, Dokutschajeff and Sibirceff only.

Thaer published, from time to time, several classifications, of which we shall cite two. One of these is the so called usual classification, the other is the classification according to value of the soil. In the first Thaer distinguished twenty varieties of soil to which he gave the following names:- Argillaceous, sticky humus (2 varieties), strongly marly, loose humus, sandy humus, heavy clayey, marly, clayey, loamy (4 varieties), loamy sandy (2 varieties), sandy clayey (2 varieties), sandy (3 varieties).

In the second classification Thaer[1] established six kinds of soil with subdivisions of each[2].

First kind. Clay soil.

Class 1. Black Klei soil. Heavy wheat soil. Marsh polder.

Class 2. Strong wheat soil. White wheat soil.

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[1] Thaer Möglinsche Annalen, Vol. VII.
[2] On the modifications of Thaer's classification see S. A. Pfannstiel, Die Bonitierungsmethoden des Ackerlandes. Landw. Jahrbücher VIII.

Class 3. Weak or poor wheat soil. Sticky clay soil, inert, cold loam soil.

Class 4. Thin wheat soil, if it is well drained, otherwise cold oat soil, poor clay soil, mountain soil, coarse loam soil.

Second kind. Loam soil

Class 1.)
Class 2.) Subdivided according to their productivity.
Class 3.)

Third kind. Sandy loam and loamy sand soil, heavy barley and dry oats soil.

Class 1. Sandy loam soil.

Class 2. Sandy loam soil in poor condition

Class 3. Loamy soil, sandy soil, drought resistant

Class 4. Like 3 except in poorer condition.

Fourth kind. Sand soil.

Class 1.)
Class 2.) Subdivided according to their productivity.
Class 3.)

Fifth kind. Humus soils. In this group belongs those soils whose predominant mineral constituents have lost their natural characteristics; for example clay loses its stickiness and sand its looseness. When a soil is rich in humus without having the characteristics of its mineral constituents influenced by the humus, such a soil will be designated as a clay soil or sand soil rich in organic matter. Humus soils can be found only on such places as have been or apparently have been under water and whose humus substance has been formed by the humification of water loving or swamp plants. Only after drainage are such places available for agriculture.

Thaer separated these soils into the following classes.

1. Medium, black barley soil.

2. Black lowland rye or oats soil.

3. Sour lowland soil.

4. Moorland soil.

Sixth kind, Limy soils.

This classification of Thaer's can be called a physical classification if its economic and agricultural features be left out of consideration. Although the humus soils are separated out as a special class or group, this is done mainly because the presence of great quantities of humus in the soil changes greatly the physical characteristics of the mineral constituent. Thaer did not discuss the characteristics of limy soils at all because, as he stated, he had never seen them.

This classification does not meet the requirements mentioned above of a scientific classification. What kind of a generalization can be made of clay soil as a natural body? Nothing more can be said of it than that it is distinguished from other natural bodies by the great amount of fine grained particles.

After we have studied this classification are we in a position to discuss the laws of soil formation? We can only say that one group has been formed on argillaceous, another on sandy and another on limy rocks, though that cannot always be maintained for clay soils can be developed from other than argillaceous rocks. Only of the humus soils can one say more than of the other groups for of this group the process of formation is given, i.e., it is formed in the presence of an excess of moisture which as we know determines many important characteristics of the soil. From the foregoing the unequal worth or value of the groups in Thaer's classification is evident.

A different classification is the one by Fr. Alb. Fallou,[1] which taken as a whole has the following structure:-

First Class: Residual soil (Primitive soils).

First group: Soils of the quartz bearing rocks.
(1. Quartzite and quartz schist soils.
(2. Soils from quartz conglomerates.
(3. Soils from quartz sandstones. The varieties are (a) Jura and Lias sandstone soil. (b) Greywacke sandstone soil. (c) Keuper sandstone soil, (d) Bunt sandstone soil. (e) Rhaetic sandstone soil.

Second group: Soils of the clay rocks.
(1. Clay rock or porphyry tuff soil.
(2. Clay slate soil.
(3. Greywacke schist soil.
(4. Soil from marly schists. Varieties: (a) soil from clay schist.

[1] Fr. Alb. Fallou, Pedologie oder algemeine und besondere Bodenkunde. Dresden, 1862, S 180-182.

Third group: Soils of the micaceous rocks.	(1.	Mica schist soil.
	(2.	Gneiss soil.
	(3.	Calcareous mica schist soil.
	(4.	Chlorite schist soil.
Fourth group: Soils of the feldspathic rocks.	(1.	Granite soils.
	(2.	Granitic soil. Variety: felsite gneiss soil.
	(3.	Syenite soil.
	(4.	Porphyry soil.
	(5.	Trachyte soil.
	(6.	Phonolite soil.
Fifth group: Soils of the Limestone, and lime-talc rocks	(1.	Jurarassic and Muschelkalk soils. varieties: (a) conglomerate (b) chalk and Plaener limestone soils.
	(2.	Jurassic dolomite soils. Variety: (a) Zechstein dolomite soil.
Sixth group: Soils of the Augite and Hornblende rocks.	(1.	Basalt soils. Varieties: (a) basalt conglomerates, (b) basalt lave, (c) dolerite soils.
	(2.	Greenstone soil.
	(3.	Serpentine soil.

Second Class. Alluvial soils.

First group. Gravel soils.	(1.	Pure gravel soil.
	(2.	Gravelly sand soil. (a) Ordinary gravelly sand unconsolidated. varieties (1) Coarse sand soil (2) shell sand (3) water worn gravel soil. (b) Cemented gravelly sand soil. Variety: (1) Cemented coarse sand soil or gravel soil.
Second group: Marl soils:	(1.	Lime marl soil.
	(2.	Clay marl soil.
	(3.	Sand marl soil. Variety: coarse marl soil.
	(4.	Talc marl or Loess marl soil.
Third group: Loam soils.	(1.	Ordinary loam soil, Varieties (1) clay loam soil (2) Mica loam soil.
	(2.	Clay soil.
Fourth group: Moor soils.	(1.	Clay moor soils (Klei)
	(2.	Braack moor soils, Varieties (1) Escher, (2) schlier and (3) Loess moor soils.
	(3.	Calcareous moor soil.
	(4.	Sand moor soil.

Special Section: The occasional accessories of soils: 1. Volcanic mud and ash, 2. Broken blocks and stone fields, 3. Torrent bowlders and other torrent deposits, 4. Peat moors with their interbedded and superposed deposits, peat, schollerde, heath, etc.

This classification belongs to the petrographic type, but the principles of classification are not rigidly maintained throughout. Moor soils are placed in the petrographic grouping by which the uniformity of the group characteristics is destroyed.

The fundamental differentiation of the soil into residual and alluvial cannot in any respect be accepted for only the parent material of the soil can be transported, not the soil itself. As we have determined definitely, the soil can retain its characteristic and essential features only so long as it remains in place. But if we so change Fallou's terminology as not to divide the soils into residual and alluvial but into soils that have developed from consolidated and unconsolidated rocks there will still be left a great deal that is open to criticism. The same type of soil may be developed from granite and from unconsolidated deposits. We know of occurrences of typical Tschernosem derived from volcanic lava, from loess, from granite and from bowlder clay. In all these occurrences there is a full and well developed set of typical features, such as structure, uniform characteristics of humus material, uniformly complex secondary developments, and others. We can undoubtedly express a much greater number of general characteristics of soils by the word Tschernosem, regardless of the rock from which the soil at any particular spot has been developed, than can be expressed by Granite soil, for by the latter we can only say that the soil was derived from granite.

A comparison of the podsol soils of the Schwartzwald[1] or of the Jakutsk region of Siberia[2] both derived from granite, with the laterite of the tropics, which has likewise been derived from granite, will convince us that these soils have nothing in common. On the other hand the podsol soils of the Schwartzwald and those of the Pskoff district in Russia derived in the latter case from bowlder clay, have a great number of important characteristics in common. Fallou's classification which was based mainly on a study of the soils of Saxony was adopted, with small changes of detail, by his students and accepted as a scientific classification of universal applicability. Fesca[3] used its main features in his description of the soils of Japan.

1 M. Müntz, Ortsteinstudien im oberen Murgtal (Schwarzwald) Mitteilungen der geol Abteil. des Kgl. württ. Stat. Landesamters, Nr. 8, 1910.
2 K. Glinka Zur Frage über den Unterschied zwischen Podsol und Moorverwitterungstypen. Pedologie 1911, Nr. 2.
3 M. Fesca, Beiträge zur Kentnis der japanischen Landwirtschaft. Berlin, 1890.

We shall now pass to the third type of classification, the chemical. As a sample of this type we select the one by Knop,[1] who separated soils into three groups.

1. Silicate soils	(Aluminum silicate soils. (Ferric oxide silicate soils. (Monoxide silicate soils. (Sand soils, silica soils.
2. Carbonate soils.	(Lime soils. (Dolomite soils or lime-magnesia-carbonate soils.
3. Sulphate soils.	(Gypsum soils. (Anhydrite soils.

In this case also we must make the same criticism as was made with regard to the preceding system. The chemical composition of soils, as promulgated by Knop,[1] gives an insufficient exhibition of the objects which constitute the fundamental bases of a classification and is in no way better than the petrographic and the physical classifications.

It is generally understood that the principle of broadest applicability in the description and classification of soils is that of genesis. The materials from which the soil has been developed have in most cases much less importance. We shall see them in some cases sink into insignificance when we compare them with the powerful influence on soil forming processes of climatic factors and the character of the vegetation. As far back as 1877 Berendt[2] protested against the definitions of soil which were given by soil investigators and agronomists of that time, and his protest was directed most strongly against the prevailing use of the term soil as identical with unconsolidated deposits. This protest made no impression however on the soil investigations in Western Europe.

In the meantime Dokutschajeff proposed in 1879,[3] the first genetic classification of soils, applying it to the soils of European Russia. His generalizations gave the basis for the establishment of a school of soil investigation which developed and broadened his fundamental principles.

Dokutschajeff took climate as his fundamental basis of classification, the action of which determined the regular distribution of soils over the earth's surface. That does not mean however that he was the first to recognize the importance of climate among the

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1 Knop, Die Bonitierung der Ackererde, 1871-72

2 Berendt, Die Umgegend von Berlin, Abh. zur geol. Spezialkarte von Preuszen, 2, H. 3, 1877.

3 Dokutschajeff. Proceedings of the Natural History Society of St. Petersburg, 10. (Russian)

processes of soil formation. He himself admitted this in crediting the idea to other investigators. The influence of climate on the processes involved in the accumulation and weathering of the organic material of the soil was long known but before Dokutschajeff's time its importance in soil classification was not recognized by any originator of a system of soil classification.

The system of classification published by Dokutschajeff in 1879 is as follows:

A. The Normal soils (i.e, Soils that have not been changed by dynamic processes other than soil making processes)

Class 1. Continental Humus soils.

(a) Gray soils of northern latitudes.
(b) Tschernosem soils.
(c) Chestnut colored soils.
(d) Red alkali soils (Solonetz soils).

Class II. Continental swamp soils.

B. Extra normal soils.

Class III. Poorly drained soil.

Class IV. Redeposited soil.

In 1886 Dokutschajeff's[1] classification appeared in revised form as follows:

A. Normal soils.

Class I. Continental humus soils.

(a) Light gray soils of northern latitudes.
(b) Gray forest soils.
(c) Tschernosem soils.
(d) Chestnut colored soils.
(e) Brown alkali soils.

Class II. Continental swamp soils.

Class III. Typical swamp soils.

B. Transition soils.

Class IV. Poorly drained soils.

Class V. Redeposited soils (in part).

C. Extra normal soils.

Class VI. Redeposited soils.

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[1] Dokutschajeff. Data on the Valuation of the Soil of Nishni-Novgorod 1886, (Russian)

The soils of the last group are not typical, according to Dokutschajeff's explanation. They are as much geological formations as soils though in time they will become true soils.

Both forms of Dokutschajeff's classifications differ from all the systems previously mentioned in their fundamental bases of grouping. They are based upon the fundamental characteristics of the soil itself rather than on the chemical, physical or petrographic characteristics of the parent rock. It is evident that of each of the continental soil groups, a series of important characteristics, common to all members, can be mentioned, each of which will suggest the laws of soil formation. When we speak of Tschernosem, for example, the external conditions by which this type has been developed, the character of the climate and the native vegetation, present themselves to us as well as a great many features of many kinds because of the conditions of formation are characteristic of Tschernosem and which are independent of the character of the parent rock. Changes in the parent rock bring modifications of subordinate importance. The same is true for the other continental humus soils.

Since the sum total of the most important features which are characteristic of the objects to be classified constitutes the fundamental basis of Dokutschajeff's classification, it is therefore a natural or philosophical system. It is however not proof against criticism. In the first place the isolation of the transition soils into a special group is not justifiable for the undisturbed Tschernosem does not differ essentially from those soils whose surface horizons are somewhat shifted by erosion, but which have not been removed from the main body of the weathered layer which was formed during the same period as that in which the surface horizons were formed. If the upper Tschernosem horizons have been completely removed from the lower, mixed, transported to another locality and there redeposited under entirely new conditions, then the matter would stand otherwise. Such a deposit is not Tschernosem, and in fact is no longer a soil of any kind, but is a mechanical deposit. When the ground moraine has been removed by erosion and its particles redeposited from river water such a process takes place. Such newly formed deposits do not constitute a moraine even though they may be made entirely of morainic material, but they constitute an alluvial deposit. For the same reason there should be no such thing as Abnormal soil in a classification system for the reason that, as pointed out by the author himself, no such soils can exist. In addition to this we cite the remark of Siberceff, that for natural bodies the terms Normal and Abnormal sound rather inapplicable.

Among the undisputable advantages of the Dokutschajeff system of classification is its capacity to develop further, a statement that can not be made of the previously mentioned systems or other systems of the same type. Although some of the soil types which have become better known to us in recent years do not appear in Dokutschajeff's system, yet they can be placed in it very easily without destroying either the soil types or the fundamental bases of

the classification system. For example, we can place Laterite, terra-rossa, etc. in the group of continental humus soils, but it is impossible to place them in any of the previously mentioned systems without destroying the characteristic features of the system. Where for example should Laterite be placed in Fallou's classification. According to the process by which it was formed it is a residual soil, but it can be formed from granite diabase and schists, so that if it be placed in the system at all it must be placed in at least three of the fundamental groups, and in one it must be called granite soil, another diabase soil and another schist soil and as Laterite it would cease to exist.

In 1886, the year in which Dokutschajeff's system appeared in its second form, Richthofen's[1] system was published. It is as follows:

A. Types of Residual soil.

1. Disintegrated rock.

   (a) Fragments accumulated in place.
   (b) Accumulations of avalanches and landslides.
   (c) Talus accumulations.

2. Deeply weathered rock.

3. Eluvial soils of plateaus.

4. Colluvial loam.

5. Laterite.

6. Organic soil, humus, moor, peat.

7. Undissolved residues.

B. Types of Accumulated Soils.

8. Coarse sediments of continental waters.

   (a) Alluvial fans of mountain torrents.
   (b) Bowldery terraces, marine bowlders, coastal bowlders, bowlders and gravels of the desert, sand.

9. Fine grained sediments of continental waters.

10. Chemical deposits in fresh water.

11. Marine soils.

12. Glacial deposits.

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[1] Freiherr V. Richthofen, Führer für Forschungsreisende, 1886.

13. Volcanic Ash.

14. Eolian accumulations.

    (a) Loess.
    (b) Loess-like soils.
    (c) Black earth, Regur, etc.

It is evident that the fundamental basis of Richthofen's classification is the same as that of Fallou. His main groups are primitive or Eluvial or residual soils and secondary or transported soils. It is to be noted that all distinction between the soil and those other land deposits, such as alluvium, moraine, marine and eolian deposits, even chemical deposits, disappear completely. According to von Richthofen no soil is necessarily eluvial; according to Dokutschajeff and the Russian school, all soils are necessarily eluvial. All other accumulations are mechanical deposits rather than soils. That soils can and do develop on marine and volcanic deposits as well as on loess is a fundamental tenet of the Russian school, but mere fresh sediments are not regarded as soils.

Richthofen outlined in his classification the following special soil regions.

I. Region of Autogenous soil development in which development takes place through the accumulation of the products of rock decomposition in place (Residual region). Under this head he includes those regions of the earth's surface in which the transporting forces are too weak to prevent the accumulation in place of the products of weathering. They are

   1. Regions of progressive Laterite development.
   2. Regions of cumulative loamy decomposition.
   3. Regions of mountain debris accumulations.
   4. Regions of plateau accumulations.

II. Regions where there is a balance between decomposition and transportation.

III. Regions of excessive denudation.

   1. Regions of glacial denudation.
   2. Regions of eolian denudation.
   3. Regions of fluviatile denudation.
   4. Regions of abrasion.

IV. Regions of excessive accumulation.

   1. Regions of marine accumulation
   2. Alluvial soils of streams.
   3. Regions of ground moraine accumulation.

4. Regions of moving sand.
5. Regions of fine grained eolian accumulation.
6. Regions of volcanic accumulation.

V. Regions of Eroded eolian accumulation.

This system was proposed by von Richthofen in 1882[1] and an attempt was made to apply it to conditions in Russia. According to von Richthofen Northern Russia is covered with glacial deposits, the central part of the country with residual soils and the southern part, with eolian Tschernosem. All three are dissected by deep river valleys.

This production of von Richthofen's, interesting as it is from the geological point of view, to all intents and purposes leaves untouched the whole matter of the zonal development of soils. Its application to Russia is open to a number of criticisms. In the first place there is no special residual region in central Russia. That areas do occur between two glacial tongues in European Russia in which the soils have been derived from various old parent rocks is undoubtedly true, but such areas may occur in the steppe region of southeastern Russia, in the glacial region of the northern part of the country, and in the granite region of the western part. Only isolated and scattered areas of this kind are found in Russia, but no unbroken zone, characteristic of central Russia.

Russian soil investigators decided immediately after its publication that von Richthofen's subdivision of Russia according to the character of its soils was not applicable, since Podsol and Tschernosem are developed on bowlder clay as well as on many other kinds of rocks.Tschernosem is not a rock at all, much less an aeolian rock, and the term aeolian rock is applicable only to the most wide spread of the parent rocks of the Tschernosem and not to the soil itself. It is also true that the term eluvial can be applied just as well to the soils of the northern part of the country as to those of the central and southern parts. South of the Tschernosem belt still other soil types occur.

Since the greater part of the surface formations which are included in von Richthofen's classification cannot be accepted as soils and his scheme of their geographic distribution can not be accepted as a scheme of soil distribution, it is impossible therefore to consider the map published by Rohrback[1] in 1892, constructed on the basis of von Richthofen's system, as a soil map at all. It shows soils, mechanical deposits and parent rocks occurring side by side and each given the same rank and categorical value. In one area true soil is shown, in another a geological formation, and in another the same color is used for several distinct soil formations. It shows Laterite, Loess and "Steppe soils", in which is included the Tschernosem of Russia, the semiarid soils of central Asia, and the arid soils of part of the Sahara all with the same color.

[1] Ferdenand, Freiherr von Richthofen, China, 2, 1882.

[1] Rohrback, Berghaus' Physikalischer Atlas, 1892.

We shall not take up the system of classification of any other west European investigator but will merely state that of western authors Hilgard[1] and Wohltmann[2] stand nearest to Dokutschajeff, and that the views of the latter have won in recent years a position of progressively greater and greater authority.[3]

We shall now proceed to the exposition of the views of Sibirceff. He worked out anew the classification of soils and conceived the doctrine of the zonal distribution of soil types in new form. He postulated that the term soil should be limited to those surface horizons of the earth's crust in which general dynamic processes of weathering operate in inseparable association with biological processes. The variations in the soils are determined by (1) The parent rock, through its chemical and physical characteristics and its occurrence, (2) organisms, through their quantity, quality, activity and chemical changes, (3) The physico-geographic conditions of the land, the changes which have been going on during the operation of the soil forming processes, and the existing geographic type. Of these conditions, that of the climate is of the most general importance. Among the climatic factors Sibirceff considers moisture the most important. On this matter he writes as follows: "Many times previously, mention has been made of the many ways by which water or moisture is important in mechanical and chemical processes and the great importance of its action. It is evident that in the same temperature zone, the weathering (Qualitative and quantitative) will vary with the variation in the degree of moisture or dryness of the atmosphere and of the rocks." He discusses also the role of moisture in the movement of soluble salts in the deeper horizons of the soil while weathering is going on. In another work[1] he writes "The moisture conditions of the American climate change in a wholly different manner. The decrease in moisture does not take place, as in southern European Russia from northwest to southeast, but from East to West. The eastern states are moist; the total rainfall being double that of our southern provinces. The western states on the other hand are very dry, and are known in America and by Americans as the "arid region". Here also the distribution of soils corresponds to that of the conditions."[1]

Although Sibirceff recognized the great importance of moisture, he could not deny that of temperature. He knew that although the Russo-Siberian Tschernosem zone forms an unbroken belt, this is due not to a uniform precipitation in all parts of the belt but to the maintenance of uniform moisture conditions through a reciprocal

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1 E. W. Hilgard, "Soils" and other works of the author.

2 Wohltmann. Handbuch der tropischen Agrikultur, 1892.

3 See the works of Professor Ramann, especially the 3rd edition of his "Bodenkunde", Berlin, 1911; The works of Treitz, Földtani Közlöny and Comptes rendus de la premiere conference agrogrologique, Buda Pesth 1909, Murgoci, Ibid, and the works carried out under the direction of Professor F. Wohltmann.

1 Sibirceff, The Tschernosem in Various Countries. Public Lecture 1898, (Russian).

relation between rainfall and temperature in the northeast southwest belt in which it occurs, by which as the precipitation decreases eastward the temperature within the belt decreases progressively because of its northeastward course. The lower temperature balances the decreased rainfall and maintains the same moisture conditions. On this matter he says: "The amount of the precipitation in the whole Tschernosem zone need not be absolutely uniform. It must be remembered that where temperature is higher the evaporation is likewise higher."[1]

We shall not take up for consideration the whole of Sibirceff's system of classification but will introduce only a section of it, one that the author publishes in his text book on Pedology.[2]

Part A. Zonal Soils. Fine grained humus soils. Fully developed soils.

Types
- I. Laterite soils.
- II. Soils from Atmospheric dust.
- III. Soil of the dry steppes.
- IV. Tschernosem soils.
- V. Gray forest soils.
- VI. Swampy podsol soil.
- VII. Tundra soils.

Part B. Intrazonal Soils.

Types
- VIII. Alkali soils (Solonetz and Solontschak)
- IX. Moor soils.
- X. Humic lime carbonate soils.

Part C. Azonal Soils, Incompletely developed soils.
Subclass: Upland soils.

Types
- XI. Imperfectly developed soils.
- XII. Coarse soils.
  - Sub-group: Alluvial Soils.
- XIII. Soils of flooded lands.

The soils of the first part or group have in general a zonal or belt like distribution over the surface of the great continental land areas corresponding in general to the climatic zones of the earth. The Laterite soils lie in an equatorial belt corresponding to the much broken and interrupted land area of the tropical zone. Northward as well as southward from this zone the loess or desert steppe soils spread themselves over the great continental plateaus as well as over the partly and completely enclosed plains. On the

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1 Sibirceff, III (Russian).

2 Sibirceff, Soils III p. 28 (Russian) and Short description of the most important soils of Russia. Publications of the Institute of Nowo - Alexandria 11, 1898, (Russian).

open grassy plains the Tschernosem soils follow and lie parallel to the loess belt while still further north or south lies the forest and Podsol soil belt and finally in the artic regions lies the Tundra belt. The zonal arrangement is most typically developed on the Eurasian and North American continents. To be sure the zonal distribution of soils must be understood to exist only in a broad and general sense. In fact soil types do not occur as unbroken belts extending entirely across the surface of any continent. They cross the continents in the form of ragged strips, break up into discontinuous and isolated areas, widen out, become narrow or occur as isolated areas at considerable distances from the main zonal sections. A complete and perfectly regular arrangement of the belts is often made impossible by changes in the character of the orographic and geological features which prevent the development of any one type of soil. As Sibirceff established the connection between the distribution of climatic factors and the soil types he made it clear at the same time that the regularity of the climatic scheme could in many cases be destroyed by air and ocean currents, local relief, general continental configuration and other causes.

Intrazonal soils originate, according to Sibirceff where local soil forming forces predominate over the general or zonal forces. The Azonal or incompletely developed soils are to be found on the borders of the true soil zones and cannot be referred to any particular zone.

A comparison of the point of view and the classification of Von Richthofen with those of Sibirceff brings out the following conclusions; while the first named author does not distinguish clearly between soils and the other surface formations, whether of subaerial or subaqueous origin, the second author, on the other hand considers soils as types of surface formations developed exclusively by soil making processes. Richthofen's regional theory is not so explicitly and definitely stated as the zonal theory of Sibirceff, while the regions of the former are not true soil regions.

From the standpoint of the fundamental requirements of a scientific classification we can make very little criticism of the classification of Sibirceff. If we designate either Laterite or Tschernosem as a zonal soil we at once in so doing place this soil before ourselves in the form of a belt or strip of more or less width in which the soil characters have been determined by the complex of soil forming forces which dominates the whole zone, and in the name of the soil we connote the laws of its formation. The most important objection of a general character that can be raised is that the proposed grouping by Sibirceff does not completely fulfill the requirements of the so-called golden rule of scientific classification. According to it where several groupings of various articles are possible, that one must be selected which is based on the greatest possible number of properties common to the bodies classified. When we place in one group, Tschernosem, Laterite and all the other zonal soils we have a group which is held together by

a single common characteristic; that of being distributed in zones or belts. If the same soils could be united into a group with more than one common characteristic such a grouping would be more useful.

To this objection some others can be brought forward. In the first place it appears that the terms zonal and intrazonal are not well selected. This terminology has been generally accepted as applicable to the soil types and varieties of certain regions though it is recognized that it applied more accurately to soil geography than to the characteristics of the soil types themselves. To accept and use it however cannot give it, because of certain principles which will be brought out further on, any value in a scheme of classification. If as Sibirceff states, the intrazonal soils are to be recognized as having been developed through the predominant influence of local soil building forces, in certain localities, over that of the zonal forces, we must with equal necessity consider small islands of Tschernosem, Podsol or other soils which have been formed in adjacent zones as intrazonal soils, for they developed in such localities through the predominance of local over zonal forces. It becomes necessary therefore to designate the same type as zonal in the one locality and intrazonal in another. So long as we concern ourselves with soil geography only we shall not fall into any error because of this, but as soon as we pass from the realm of soil geography to that of soil classification this fact must be taken into consideration.

Whatever the group of azonal soils may signify there is no necessity for example to designate the alluvial soils as azonal, merely because in their formation other dynamic processes were involved as well as soil forming processes. Such processes were involved in the formation of glacial and eolian soils so that there is just as much reason to designate these latter as azonal soils as to so designate the alluvial soil. In the soils of river valleys we find Moor soils, Podsol soils, gray forest soils and other types, so that they should in fact be grouped with the other types since they have often developed into such. It would be possible to use expressions such as; alluvial Tschernosem, alluvial Podsol, alluvial moor soils, etc., when however, the alluvial processes (the diluvial and eolian as well) conceal the results of the operation of the soil forming processes, it is better not to designate such material as soil at all but as alluvium, diluvium, etc. and to place it in a group of mechanical deposits. For the same reason we find it impossible to place coarse soils, those which through washing or the action of the wind have been robbed of the greater part of their fine earth or humus material in a special group. Such soils differ widely among themselves in their deeper horizons. That arises from the fact that they may have been developed from Tschernosem, Podsol, or any other soil type. If they show traces of type characteristics, they can always be designated as washed out Podsol loam, blown out Tschernosem loam, etc. If, however, no trace of type characters exist then the material is no soil but rock. That is the essential reason that compels me to discard zonal, azonal and intrazonal as classification criteria.

Before we take up for consideration any new classification systems we shall examine into the progress of pedology in other directions more or less closely connected with the question of classification.

Although Dokutschajeff and Sibirceff described the soil as the product of the weathering of the present earth's surface, and considered also the study of the deeper lying parent rock as indispensable, yet they considered the soil in the restricted sense as that portion only which carries the organic matter. The deeper lying horizon which has been strongly attacked by the soil forming forces they called the subsoil. These authors as well as other Russian pedologists of the same period refer in their descriptions, usually, to such changes in the parent rock as can be shown to have been produced by the soil building processes. For example, Georgiewski referred, in the description of the forest loam in the Poltawa district to such horizons which lay below the humus bearing layer as a reddish brown loam, 1 to 2 Arschin thick, and unaffected by acid, underlaid by brown, highly calcareous loam with large concretions of lime carbonate. These two horizons were considered by Geogiewski to have been subjected to the action of the soil building forces, and the transportation of the carbonates from the upper to the lower layer was explained as the result of the more complete leaching of the upper soil horizons by the greater moisture present in forest covered areas.

Without reference to this work the investigators during the eighties and nineties gave the greater part of their attention to humus horizons of the soil. Their structure and development, especially in relation to their chemical composition and physical properties, were carefully investigated. This exclusive study of the surface horizons was due to the circumstance that the investigators of the eighties and nineties worked along practical lines such as the valuation of the soil, and the data available to them in the necessary analytical work were very limited.

About the close of the nineties the results of a great many studies of the deeper lying weathered horizons of the Tschernosem region as well as the forested zone of Russia appeared in scientific literature. Bogoslowski[1] pointed out to the Russian investigators the great diversity of the deeper lying weathered horizons and the absolute necessity of studying them carefully whether in the Steppes or the forested regions of European Russia. In attempts at classification he considered it necessary to include the whole weathered layer of the earth's crust as the object of classification.

Wyssotzki[1] was the first to attempt a classification according to the chemical composition of the deeper horizons of the weathered layers in Russia. The soluble salts prevailing in post Tertiary formation and other kinds of parent rocks, can, according to the author be grouped under three heads according to the degree of their

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1 Bogoslowski, Bulletin du Comite du geologie de St. Petersburg, 18.
1 Wyssotzki, "Pedologie" 1899, No. 1 (Russian).

solubility; 1. Those soluble only in water saturated with carbonic acid, such as carbonates of the alkaline earths, mainly lime carbonates. 2. Slightly soluble in pure water, mainly gypsum. 3. Readily soluble salts such as common salt and its associates such as KCl, Na_2SO_4, Na_2CO_3. In the outline proposed by Wyssotzki the subsoils of European Russia, insofar as they are related in their chemical characteristics to the soil forming processes, lie in north-northwest south-southeast zones. The following zones were differentiated:

1. Completely leached subsoils and substrata containing none of the soluble salts named above.

2. Subsoils in which, from a given depth downward, the salts of the first kind, mainly lime carbonate are present.

3. Subsoils in which, from a certain depth downward, gypsum, in addition to the above named salts, is present.

4. Subsoils which contain all the salts mentioned.

By way of explanation it should be mentioned that in the above discussion those salts are included which along with other groups of compounds accumulate during and as a result of the action of the soil building processes. When we speak of the low content or absence of lime carbonate in the forest regions of European Russia we refer only to the absence of carbonate that formed in the subsoil while soil making was in progress. It is well known that, in the steppe Tschernosem regions, lime carbonate accumulates in the subsoil during the development of the Tschernosem over a parent rock which carries no lime carbonate. In a forest soil on the other hand, no lime carbonate will form while the soil is developing.

In the following table constructed by Wyssotski he compared the subsoil types proposed by him with the soil types and plant zones of European Russia.

Subsoil	Soil according to Sibirceff	Vegetation
1. Thoroughly leached	Podsol Soils	Unbroken mixed forests.
2. CaCO[1] is present.	Gray forest soils.	Deciduous forests. Dark colored deciduous forests mainly oaks, on clay soils
3. $CaCO_3$ and gypsum	Tschernosem	Steppes. Forests only in the most leached localities.
4. $CaCO_3$, gypsum and NaCl with associates	Soils of the dry steppes and alkali soils.	The steppe formation of the deserts and semi-deserts.

1 In this case the $CaCO_3$ is not a product of the soil forming processes now operating in the region but is a residue from the accumulation of a preceding steppe period.

The scheme, as Wyssotzki says, cannot be universally applied in detail. It is accepted however as the expression of a broad relationship. On the basis of our knowledge of the soils of Siberia and northern Manchuria it can be applied as a whole to the soils of the greater part of Asia. Exceptions however are necessary because of the occurrence in both eastern and western Siberia of parent rocks, saturated with soluble salts accumulated in earlier geological periods and preserved in the rocks. In many places, even in the forested steppes the subsoils or substrata contain such salts to an extent such as usually occur only in dryer and, in Asia, more southerly regions. They are however, often leached to great depths, but they still remain in the deeper lying horizons.

Similar observations were made by Blanckenhorn[1] in northern Africa, although in that region entirely different soils and different plant formations predominate. In this region the accumulation of lime carbonate and gypsum and other easily soluble salts is dependent upon the moisture of the various horizons.

This sketch of Wyssotzki's results establishes once more the close connection between the deeper soil horizons and those on and near the surface. For that reason the term Tschernosem applies not merely to the dark colored or humus layer but to all the weathered soil layers that were produced contemporaneously with the surface layer. It includes the thick upper part of the weathered layer colored dark by its content of organic matter and also its lower layer characterized by its high content of carbonates and occasional content of gypsum. The conditions which caused the accumulation of organic matter, the moderate amount of moisture, caused the accumulation of the salts also.

In this way the Wyssotzki scheme makes clear the influence of moisture on the whole soil layer. We have pointed out before that the importance of moisture among the soil forming processes was raised by Sibirceff, but Kostytscheff[1] devoted his special attention to it. Hilgard[2] also, in comparing the soils of the dry regions of North America with those of the moist regions, emphasized its importance.

Moisture however, which is thus raised to the position of a fundamental basis of classification is itself the product of several factors. The amount of moisture present in various soils is dependent not simply on the quantity of the precipitation but on the temperature, the humidity of the air, the relief of the land, the character of the parent rock and the plant cover. The temperature determines the rate of evaporation of the precipitation and in this way influences all the processes which have in any way a close

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1 Blanckenhorn, Zeitschrift der deutschen geologischen Gesellschaft. 53, 1902.

1 Kostytscheff, The soils of the Tschernosem region of Russia, T.I. 1886. (Russian).

2 Hilgard, Wollny's Forschungen auf dem Gebiet der Agrikulturphysik, XVI. I und II.

relation to evaporation; such as the capillary rise of moisture, the processes of salt crystallization, the rate of decay of the organic matter and in general the energy of the weathering processes. In warm regions temperature influences the color of the soil also as has been shown in the investigations of Laterite, terra rossa and the soils of the subtropical, semi-arid regions. In tropical latitudes the dehydration of hydrated iron oxide and its conversion into the less hydrous Turgite is dependent upon the temperature. Blanckenhorn noticed in Algeria that along the Mediterranean the amount of precipitation in places was equal to that of the Mediterranean region of southern Europe but that the evaporation was but little less than that in the desert farther south. This fact explains the capillary rise of the carbonate solutions and the formation of a lime hardpan[1] layer, a feature rarely seen in southern Europe. The zonal distribution of the soils in Eurasia can be explained only when one recognizes that the temperature is a factor in the matter, in addition to the precipitation. This is made evident by the fact that no soil zone of this great area receives the same precipitation throughout its area of occurrence. The nearer Asia is approached, the smaller becomes the amount of precipitation in the same soil zone; at the same time, however, the soil zones move northward into regions of lower temperature, where the evaporation is smaller, thus maintaining essentially the same degree of moisture. In European Russia we can find not only separate localities but whole regions with uniform precipitation in which however diverse temperatures have produced diverse soils.

While we recognize moisture in this way as the most important basis for soil classification, we do not claim originality for the idea, but on the other hand we merely use the observations and conclusions of Russian and West European investigators. At the same time we do not underestimate the importance of temperature, whose influence on the formation of the soil is only less visible than is that of moisture.

When we give the soils that are to be classified the nomenclature originating with Dokutschajeff and Sibirceff we include under the respective type names not merely the humus horizons but the whole thickness of the weathered layers of the existing earth's surface. In the following pages therefore we shall have to describe the soils in their whole depth, or attempt to do it as far as the available data will permit.

When we include climate and the external soil forming forces in general as important factors in the soil forming processes, we must admit, at the same time, that they have not produced everywhere the same result. Chemical composition and physical character of the parent rock interrupt the development of the soil type that would take place normally under the action of the external forces.

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[1] Bläckenhörn, Zeitschrift der deutschen geologischen Gesellschaft, 53, 1902.

The humus carbonate soils such as the Rendzinas, which occur in the Podsol zone and which differ widely from the latter in essential features, constitute a good example of the influence of the parent rock on the soil forming processes. Such an example compels us to place such soils in a class to themselves because their development and their characteristics are both visibly influenced by internal conditions, the character of the parent rock.

We propose to designate them as endodynamomorphic soils to distinguish them from the ektodynamomorphic soils in which external factors predominate over the internal. Skeleton soils are, in part, to be considered as endodynamomorphic, especially those on which the external conditions have exercised no influence. If on the other hand soils derived from granite have the characteristics of Tschernosem or those derived from clay slates show evidences of Podsol characteristics, they will be placed without question in corresponding groups of Ektodynamomorphic soils.

The endodynamomorphic soils may be looked upon as soils in a transition stage. The Ektodynamomorphic soils are likewise transition soils in so far as they are liable to change with changes in external conditions, especially of climate. Subjected to such conditions they will change from one type to another. Such a change has been observed in Tschernosem. If this soil becomes covered with forest and the upper soil horizon is thus made permanently more moist it will change to a gray forest loam. Such a change of a more fertile soil to one less fertile is designated as a degradation. Theoretically the opposite change, from a less fertile to a more fertile soil is possible, though up to the present time no one has demonstrated unmistakably the existence of such a soil.

That endodynamomorphic soils have the capacity to change independent of changes in external conditions can be shown by reference to two possible cases. Let us suppose that in a zone in which normally Podsol soils predominate, a marly rock is present as is the case in many parts of Poland. On such a rock dark colored carbonate soils, rich in organic matter develop which differ very greatly from the adjacent Podsol loam developed on loess or glacial deposits. The first stages in the development of such a soil are strongly influenced by the chemical composition of the rock which prevents or delays the decomposition of the organic matter and favors the accumulation of humus.[1] As we know however, the depth to which the humus substances penetrate is not without a limit. In this case it

[1] Wollny, Die zersetzung der organischen Stoffe und die Humusbildungen, 1879.
Kostytscheff, The Soils of the Tschernosem Region of Russia, T. I. (Russian); Bildung des Tschernosem, St. Petersburg, 1886; The Formation and Characteristics of Humus. Work of the Natural History Society of St. Petersburg, XX pages 123 to 128 (Russian);
Kossowitsch and Tretiakoff, Journal of Experimental Agriculture, III, 1902 (Russian)

will not be very great because the lime carbonate holds the humus substances. The weathering of the marl will not stop however with the formation of the humus horizon but will go much deeper but in the deeper layers the marl will be subjected to the action, mainly of carbonated water rather than humus solution. While the humus layer was developed on the surface from the marl, in the deeper horizons no such formation can take place but in its stead there will develop a yellow or brown loam. When however the humus layer no longer contains any carbonate, and beneath it a loam likewise free from carbonate has been developed, the conditions for the accumulation of humus no longer exist and thence onward the climatic soil forming forces will dominate the soil forming processes. In the particular case these are so combined as to be unfavorable to the accumulation of large amount of humus, especially its less readily decomposable compounds. The black soil (usually designated as Rendzina) will thence forward change gradually, its humus will decompose and pass into less stable forms and finally from the Rendzina a typical Podsol is developed. An opportunity to prove the soundness of these theoretical considerations by observation is presented to us in the vicinity of Cholm, in the province of Lublin, European Russia.

For the second possible illustration let us suppose that in a Tschernosem Steppe there are occurrences of granite. While Tschernosem is being formed on the fine grained fragmental material, on the granite on the other hand, which succumbs with difficulty to the action of the soil forming processes, coarse "skeleton" soils will develop on which a humus horizon is barely distinguishable. The humus substances do not penetrate to great depths, but their decomposition is more rapid and the action more energetic than in that of the fine grained rock. The humus forming vegetation is less luxuriant and the mixing of the humus material with the mineral part of the soil is less intimate on account of the coarseness of the parent rock. These phenomena will appear in the first stages of soil formation. When however the material in the surface horizon has become so fine grained that the decomposition of the humus is more gradual its incorporation in or mixing with the mineral constituents of the soil will become gradually more complete. The humus will accumulate and the humus horizon corresponding to that of the adjacent Tschernosem will develop. Beneath this the brown or yellow Argillaceous characteristic of all phases of the deeper horizons of the Tschernosem will develop slowly forming a gradual transition to the unchanged granite below. Such transitions may be seen in the vicinity of Tscheljabinsk, in places also in the southwestern part of Russia in the province of Kiev and in Podolia.

Such examples are sufficient to establish the existence of the endodynamomorphic soils as mere transitory bodies and their inevitable change into ektodynamomorphic soils.

Ektodynamomorphic soils may be grouped into the following classes on the basis of the relative amounts of moisture that reach the surface horizons in the various parts of the earth during the operation of the soil forming processes:

I. Soils of optimum moisture content.

II. Soils of average moisture content.

III. Soils of moderate moisture content.

IV. Soils of insufficient moisture content.

V. Soils of excessive moisture content.

VI. Soils of temporarily excessive moisture content.

At the present time we can not specify definite amounts of moisture in each of these cases but must content ourselves with general comparative statements.

When sufficient study has been devoted to the various soil zones or regions, it is possible that each region, according to Treitz,[1] can be described in terms of a definite saturation deficiency.

To the first four classes belong those soils which have been developed under the influence of the moisture coming immediately from the atmosphere. To the last two groups belong those which occur in areas of negative relief and which have received their moisture not only from the atmosphere directly but also in the form of seepage from the surrounding higher lying areas and from the ground water of the immediately underlying surface.[2] In the soils of the first four groups the soil horizons have developed normally and typically, that is, under the influence of downwardly percolating moisture. In the last two groups the "Glei" horizon, developed under the influence of ascending moisture, is often present.[3]

1. Soils developed under Optimum Moisture Conditions.

These soils originate under the influence of a large amount of moisture and high mean annual temperature. Under these conditions the greater part of the organic substances mineralize completely so the soils are low in humus. The salts which develop through the decomposition of the organic matter and the weathering of the silicates are completely leached from the weathered material. The sesquioxides are not dissolved, and removed but accumulate in the soil. Along with the hydration of the sesquioxides clay is formed. The silicic acid of the silicates is carried out of the weathered material in solution. Carbonated water and high temperature are apparently the

[1] P. Treitz, Was ist die Verwitterung? Comptes rendus de la premiere conference internationale agrogeologique. Budapest, 1909.

[2] Neustrujeff, On the Question of Normal Soils and the Zonality of the Soils of the Dry Steppes. "Pedology", 1910 Nr. 2, (Russian)

[3] The term "Glei" was first introduced to science by Wyssotzky, "Pedology", 1900 (Russian).

predominant factors in the weathering. Under these conditions the hydrolysis of the silicates and aluminum silicates takes place rapidly.[1] The result of this action is the splitting off of important amount of the mineral bases which are found in soil solutions as carbonates. It is possible that the alkaline carbonates take part in the solution of the aluminum which is deposited rather abundantly in the soils of this group as concretions of hydrargillite.

To this group belong Laterite, the Terra-rossas of moist subtropical latitudes, apparently also the yellow soils which have been observed in abundance in Southern France and which I have identified in samples from Japan.[1]

2. Soils Developed Under Average Moisture Conditions.

These soils originate under such moisture and temperature conditions as are sufficient to prevent the accumulation of large amounts of unstable humus compounds. A complete mineralization of the organic material of the soil does not take place, its oxidation halting usually with the development of intermediate stages of decomposition. The so-called Crenic and Apocrenic acids constitute examples of such intermediate forms. When these compounds are present in large quantities no carbonates are formed and the other easily soluble salts are leached out. The soils formed in this way will display the action of weathering by acids. As a consequence not only the bases but the sesquioxides also are removed from the eluvial horizon so that these horizons have an excess of silica.

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1 That the weathering of the silicates and aluminum silicates under the influence of pure water as well as of carbonated water is nothing more than the hydrolysis of these minerals is proved by numerous experiments and by observation. The following references to the literature of the subject is cited: Kenngott, Journ. für prakt. Chemie, 101, S. 1 und 474; 103, S. 289 bis 305. Doelter, Tschermaks min. und petrog. Mitteilungen 10, 1890, S. 319 bis 330. Steiger and Clarke, Bull. U. S. Geol. Survey 167, 1900. Forchhammer, Poggend. Annalen, 1835, 35, S. 351 bis 356. Rogers, Sillimans Journal, 1848, 2 (5). Daubreé, Comptes rendus, 1867, 14 S. 339 bis 345, Stoklasa, Landwirtsch. Versuchst. 27, S. 197 bis 207. Beyer, Landwirtsch. Versuchst. 14, 1871, S. 314. Fittbogen, Landwirtsch. Jahrbücher, 1873, R. Mueller, Tscherm. min. und petrog. Mitt. 1877, H.I. Sicha, Untersuchungen über die Wirkung des bei hohem druck mit CO_2 gesattigt. Wassers auf einige Mineralien. Inaug. Dissertation, Leipzig, 1891. F. Sestini, Proceedings of the Tuscan Scientific Society; Pisa, 1901 (Italian), Johnstone, Quart. Journ. of The Geological Society, of London, Vol. XIV, 1889 pages 363 to 368. Johnstone, Proceedings of the Royal Soc. Edinburg, 127, 128, 1888, Vol. XV. K. Glinka, Investigations in the Realm of the Processes of Weathering, Proc. of the Imp. Soc. of Nat. Hist. of St. Petersburg, 34, part 5 (Russian) K. Glinka, Pedology, 1908, pages 204 to 209 (Russian) and Neue Richtungen in der Bodenkunde "Pedologie", 1910, I by the same author.

2 The samples were collected in Japan By T. Gordiejeff.

The weathering of certain zeolites by this process was observed by us on Zchra-Zkaro[2] Mountain in Transcaucasia. The dissolved bases were in great part carried out of the soil layer and the sesquioxides and manganese oxides formed in combination with the organic substances, either separate concretions or distinct illuvial horizons. The Podsol soils, gray forest soils and the soils described by Ramann as Braunerden belong in this group.

3. Soils Developed Under Moderate Moisture Conditions.

These soils originate in the presence of a quantity of moisture sufficient for the development of a rich grass vegetation, but which is not sufficient for a rapid and energetic decomposition of the organic substances. For this reason humus accumulates, especially the less stable compounds, in considerable quantities.

That part of the organic matter oxidizing completely supplies abundant carbonic acid which, in the process of weathering, forms carbonates. Lime carbonate originating in this way does not extend to great depths and forms a continuous carbonate horizon beneath the humus layer in those places where the parent rock is rich in lime. This process can be seen in the Tschernosem profile on the plateau of Gocktscha Lake in Transcaucasia. Gypsum often accumulates in the lower horizons while the carbonates of the alkaline earths are accumulating in the higher. The other more soluble salts are to a great degree removed by solution from the soil layer, though they are often present in the ground water. The decomposition of the aluminum silicates proceeds, especially in the humus horizons, by hydrolysis, forming clays, though it takes place slowly. To this group belongs the Tschernosem, perhaps also the Regur of India. We mention the later conditionally because we are not in possession of sufficient information as to the morphology and structure of this soil to enable us to place it definitely.

4. Soils Developed Under Insufficient Moisture Conditions.

Of this group we know, best of all, the soils of the dry steppes whose conditions of formation we shall describe briefly. The vegetation, because of the small amount of moisture, is not so well developed by far as in the Tschernosem steppes, and for this reason the soil has a small amount of humus. In the soils of the semi-arid portions of European and Asiatic Russia the quantity of organic matter decreases gradually southward. In the northern varieties of these soils there is a distinct difference in color between the humus layer and those lying beneath it, a feature that is rarely found in the more southerly varieties. The humus horizons of these soils usually have no definite structure and when any is present it is seen only in a thin layer of the surface horizon. The carbonates of the alkaline earths, mainly lime carbonate and gypsum are

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2 K. Glinka, Investigations in the Realm of the Weathering Processes. Proceedings of the Imperial Society of Natural History of St. Petersburg, 34, part 5 (Russian)

universal constituents of the profile of the loamy varieties of these soils, but the horizons in which they accumulate lie nearer the surface as a rule, than in the preceding soils. Chlorides and sulphates have disappeared from the upper horizons. The silicates and aluminum silicates are usually but slightly decomposed and practically no transfer of bases and silica from one horizon to another can be detected by chemical analysis. The Chestnut Colored soils belong in this group. These are the brown and gray soils of the southern part of the Wolga region, The Crimea, Transcaucasia, the Khirgez steppes, the provinces of Jenisseisk, Transbaikalia, Turkestan, Manchuria, a part of the Hungarian "pouszta", the Steppes of Roumainia, Spain and the Western States of North America. The red colored soils of this group which are looked upon as the soils of the dry steppes of sub-tropical latitudes (Australia, South Africa) and the warmer regions of the temperate zone have been studied very little but if we may base our opinion on samples received from Australia and Salamanca in Spain we may conclude that they have, so far as structure is concerned, much in common with the soils of the dry steppes of Turgaj, Akmolinsk, and the country lying around the shores of the Caspian sea,

A second subgroup is formed by the desert formations known as the gypsum crust, lime carbonate crust and brown protecting crust[1] known to occur in South America, Syria, Palastine, Arabia, North Africa, in places also in Southern Europe[2] and in Transcaucasia[3] (in the vicinity of Erivan). Their morphology and genesis are not well understood.

5. Soils Developed Under Excessive Moisture Conditions

The soils of this group are formed under the influence of excessive moisture which saturates the upper horizons and sometimes also the lower. Under such conditions the decomposition of the organic substances is hindered. Along with the partly oxidized compounds of organic material carbonized forms of half decomposed organic matter are formed also, the progressive action of the moisture on the decomposing plant remains as well as on the minerals of the parent rock causes an energetic splitting off of the bases, and their conversion into bicarbonates especially in the lower less organic horizons of the soil profile. Weathering takes place by hydrolysis, in which the iron separates as ferrous iron, though it is soon leached out of the surface layers. As consequence of the presence of reducing compounds sulphides, Vivianite, Siderite, and Ankerite are sometimes formed. The soil water has no means of draining away and for this reason it becomes rich in easily soluble salts which during dry seasons rise to the surface and crystallize out. All these features became more and more pronounced, the more

1 Blanckenhorn, Zeitschrift der deutsch geolog. Gesellschaft, 1902, 53, Heft. 3.
2 Blanckenhorn.
3 Dokutschajeff, Preliminary communication on The Investigations in the Caucasus, Tiflis, 1889 (Russian).

permanent and the more thorough is the saturation of the soil with moisture. If the saturation becomes less complete many of these features become less pronounced in their expression or disappear entirely. The moor soils belong in this group. The group seems to have a subgroup in which the peat soils of the Tundra and mountain peaks are included. Soils of the mountain peaks with the same morphology have been seen by me on the Zchra-Zkaro and the Ali Bek in Transcaucasia.

6. Soils Developed Under Conditions of Temporarily Excessive Moisture

Soils of this group, soils temporarily wet either on the surface or in the subsoils, are known to occur both in the Tschernosem, as well as in the desert steppes. These are the so-called alkali soils which according to their structure are divided into the Alkali soils with characteristic Structure and those without definite structure. Both kinds contain the easily soluble salts among which $NaCl$, Na_2SO_4 and Na_2CO_3 or $NaHCO_3$ are of special importance. The upper horizons of the former subgroup often contain none of the first named salts but the deeper horizons contain them. Where $NaHCO_3$ is present and chlorides are entirely absent or are present in very small quantities, the following transformation takes place: $NaHCO_3$ in the surface horizons changes to Na_2CO_3 which dissolves humic acid and prevents the floculation of the fine grained suspended soil material. In this state the material passes downward with a part of the alkaline humates. At some depth a change of the Na_2CO_3 to $NaHCO_3$ takes place and the alkaline humate is precipitated along with the suspended material brought from above, the latter being precipitated through floculation. In this way is formed a leached upper horizon, of coarse texture and a lower horizon which on drying breaks up into columnar, prismatic or irregularly formed pieces.

In the structureless alkali soils in the upper horizons of which chlorides and sulphates are present in considerable quantities and in which relatively small amounts of soda are present, no transportation of humic acid colloid solution or of suspended matter can take place because of the floculating action of the positive ions of the electrolytes present. On this account therefore no translocation of material from the upper to the lower horizons can take place and the horizons of the soil maintain the same texture throughout. Through a great many transition stages the alkali soils merge into the Zonal types of the zones in which they lie. There are Tschernosem soils, Chestnut Colored soils, and brown soils having the structural characteristics of the Solonetz soils.[1] In the same zones there are transitions to Solontschak soils.

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[1] There is no word in English carrying the same meaning conveyed by the expression alkali soils with definite structure. To avoid the use of so long a phrase the Russian word Solonetz will be used in the following pages while the word Solontschak will be used for alkali soils without pronounced structure. C.F.M.

The soil classification scheme here proposed constitutes, to be sure, only a short general summary attempting as far as possible to give a comprehensive exposition of our knowledge of the subject. We regard it as by no means the last word to be said on the subject. In tabular form we present the following general scheme including the principal kinds of soil:

I. Ektodynamomorphic Soils.

1. Soils developed under optimum moisture conditions.

   (a) Laterite.
   (b) Terra-Rossa.
   (c) Yellow soils.

2. Soils developed under average moisture conditions.

   (a) Podsol soils.
   (b) Gray Forest soils.
   (c) Degraded Tschernosem.

3. Soils developed under moderate moisture conditions.

   (a) Tschernosem (and Regur?).

4. Soils developed under insufficient moisture conditions.

   Group A.

   (a) Chestnut colored soils.
   (b) Brown soils.
   (c) Gray soils.
   (d) Red soils.

   Group B.

   (a) The Brown crusts.
   (b) The Lime crusts.
   (c) The Gypsum crusts.

5. Soils developed under excessive moisture conditions.

   Group A.

   (a) Moor soils (Peat and Muck soils).

   Group B.

   (a) Soils of the mountain meadows.
   (b) Peat soils of the dry Tundras and mountain peaks.

6. Soils developed under temporarily excessive moisture conditions.

   (a) Solonetz soils.
   (b) Solontschak soils.
   (c) Transition forms of a.
   (d) Transition forms of b.

II. Endodynamomorphic Soils.

(a) Rendzina.
(b) Various skeleton soils.

Soil classification in this form presents only an exhibition of the Variety of soil types from the qualitative and in part quantitative viewpoint. Since however the parent rock may have widely varying mimerological as well as mechanical composition, it is evident that a series of secondary bases of grouping must be included in a complete classification scheme. The principles of differentiation of the several types will be fully discussed under the descriptions of the types themselves in the following pages. I present below a sample section of a complete classification.

Types of Soil	Varieties according to petrographic composition	Varieties according to mechanical composition.
Tschernosem.	Tschernosem from Loess	Argillaceous Tschernosem
	" " Granite	Loamy "
	" " Basalt	Sandy loam "
		Sand "
	- and so on -	
Podsol	Podsol on bowlder clay	Clay Podsol
	" " loess	Loam "
	" " granite	Sandy Loam "
		Sand "
	- and so on -	

Such subdivisions must be given for every soil type in the classification proposed above. We regard all soils, whose type characteristics have been determined by the character of the processes that have acted upon them as belonging to the same type, regardless of the petrographic or mechanical composition of the parent rock from which they have been derived. The other characteristics such as the petrographic composition of the rock, its plasticity, looseness, etc. which influence the soil in a less fundamental way we regard as of secondary importance. We will remark in passing however that the investigator must know first of all, with what type of soil he is dealing, whether it is a Tschernosem, a Podsol,

a Laterite, or some other type, for this furnishes him with a knowledge of the conditions under which the soil has been developed. The investigator is then in a position to investigate the characteristics which have exerted the minor influence on the development of the soil.

Many of the soil types named in the preceding tables form, as has been stated already, broad, almost unbroken zones or belts which often include, in length and breadth large areas. In European and Asiatic Russia these zones trend northeast and southwest following each other in regular order from south to north, so that a traveler who crosses Russia from the White sea on the north to the Caspian sea on the south, or crosses Asiatic Russia from the Obi river to Tashkent will cross in both journeys the same soil type zones and in the same order. The corresponding zones in North America are different in their trend.

On both sides of the equator lies a zone, almost unbroken within the continental area, of Laterite and Terra Rossa, changing gradually both northward and southward to the red soils of the sub-tropical semiarid steppes. These zones are in their turn replaced by the soil types of the deserts of sub-tropical and temperate latitudes, as well as by the types of the dry steppes of the temperate zones. Tschernosem soils make up at least two, possibly three zones on the earth's surface; one includes the Tschernosem of Europe, Asia and North America, the second that which is developed in the warmer part of the temperate zone of the southern hemisphere seemingly best developed in the Argentine. It is possible also that the same soil will be found in South Africa and Eastern Australia. In the tropics of India we know of the existence of the Regur, a soil very much like the Tschernosem, and it is possible that we shall find similar soils where Laterite and Terra Rossa changes gradually to the red soils of the sub-tropical semi-arid steppes, and in other places in the tropics.

The typically developed Podsol soils of the northern hemisphere, developed in the forested regions of Europe, Asia and North America, have been identified in the southern hemisphere, in considerable areas in the southern part of South America.

The regularity of the geographic distribution of all these soil types is interrupted in various ways. In the vicinity of the sea the moisture of the air and the precipitation are usually greater than in the interior of the continents on the same latitudes so that some of the types especially those developed under rather low moisture conditions rarely extend to the coast line. Mountain ranges deflect the belts also. The extent to which the ocean can influence the distribution of the soil types can be judged by a study of the geography of the Tschernosem of Europe and Asia. As this soil belt nears either the Pacific or Atlantic ocean it bends southward as if it were seeking a region of higher annual temperature and higher evaporation. In Europe as well as in Asia the zone does not reach

the sea for the climatic conditions near it do not favor the existence of a continental climate or a continental soil type.

The influence of mountain ranges may be seen in many places. The dry steppe soils of the southern Volga region are replaced by Tschernosem as they approach the Caucasus Mountains. The Ural and Altai ranges and the mountains of Siberia which trend across the Tschernosem belt cause the development of soils characteristic of moist climates. Where the "Pouszta" of Hungary, with its Chestnut Colored soils approaches the mountains the latter change gradually, first to Tschernosem and high in the mountains, where timber covers the surface, to Podsol soils.

We shall describe later the details of the soil types and discuss the distribution of the soil zones. In passing I will state that the distribution of the soil belts is regular both horizontally and vertically. The existence of vertical zones was established for the Caucasus Mountains by Dokutschajeff.[1] It does not follow however that in that mountain range the same soil belts are always to be found at the same elevation. Such a condition cannot exist for uniform climatic conditions do not exist over the whole range.[2] If we compare with each other mountain ranges having the same climatic conditions entirely around them we find in climbing them, the same succession of soil belts at all points. This may be seen in at least two places: From Erivan to Doratschitschag and on the top of the Ali Beck mountain and from Erivan to Alexandropol and higher. The immediate vicinity of Erivan is a desert steppe with gray desert soil which is derived in part from unconsolidated deposits and in part from basalt lava. As we rise higher we enter a zone of typical Tschernosem, which begins to show signs of degradation in the vicinity of Doratschitschag and a little higher grades into typical gray forest soil covered mainly with oaks. Still higher well developed Podsol soils are found while above this lie dark colored wet meadow soils and above them the peaty soils of the mountain peaks. In passing therefore from an elevation of 3000 feet above sea level at Erivan to the top of Ali-Beck, about 60 wersts, we find all the soil belts that we find in traveling from Baku to North Cape on the Arctic ocean. If we climb from the station Michailowo to Borshom and from there through Bakuriani to the top of Zchra-Zkaro we can see again the change from Tschernosem to gray forest soils and the latter into Podsolic soils in the vicinity of Borshom. Still higher we find the dark colored wet grassy (Wiesen) soils which are replaced on the summit of the mountain by brown peaty soils.

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[1] Dojutschajeff, On the Theory of the Zone in Nature. The Horizontal and Vertical Zones, 1899. For the Tian Shan, see: Krasnof, Proceedings of the St. Petersburg Natural Science Society, 18, 1887 (Russian).

[2] The law of the change of temperature with change in elevation is not equally well expressed in the various regions of the Caucasus.

In recent years the vertical zonality of the soils of the Altai Mountains, the Mountains of the Syr Darja region and the Semiretschje has been proved.[1]

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1 Neustrujeff, Arbeit der Bodenerforschungs Expeditionen für die Untersuchung der Kolonisationsregionen des asiatischen Russlands, 1908, Liefer. VII. Prassolof, Ibidem, Lief V. Bessonof, Ibidem, Lief VI. Smirnof, Ibidem, Lief IV. K. Glinka, "Pedologie" 1900. K. Glinka, Vorlaufige Bericht über die Organisation und die Vollziehung der Bodenerforschungen in asiatischen Russland in Jahren 1908, 1909, 1910 und 1911. St. Petersburg, Verlag der Uebersiedelungsverwaltung.

THE CHARACTERISTICS OF THE SOIL TYPES AND THEIR VARIETIES.

Part I. Ektodynamomorphic Soils

1. Soils Developed Under Optimum Moisture Conditions.

These soils, so strikingly characteristic in color and thickness have long been an object of attention by travelers and investigators. As early as 1807 Buchanan[1] proposed the name "Laterite" for the red colored soils of the tropics.[2] The term has become recognized in scientific literature and has been used extensively, though often misused, since the name has been applied to every red colored soil in tropical or sub-tropical latitudes. Gürich[3] protested in 1887 against such a misuse and maintained at the same time that true Laterite is characteristic of tropical regions only.

Undoubtedly at least two groups of red colored soils have been observed which, according to the differences between their conditions of formation, their composition and physical characteristics, are widely different. The first of these groups is characteristic of regions with heavy rainfall and belong therefore to the Laterites and related soils. The other group is found in the dry steppes of the tropics and has, with the exception of the color, nothing in common with Laterite.

The red colored soils of this latter group that are found in Spain,[4] Brazil, Australia and Africa often contain secretions or concretions of lime carbonate, which is a sign of insufficient moisture. Our brown and gray soils of the dry steppes which are characteristic of the extreme desert areas of the temperate zone may possibly be analagous to these soils, differing in the red color only on account of the higher tropical temperature. We have a sample of such a soil from the subtropical desert steppes of Australia the investigation of which shows that it has nothing in common with the Laterite soils of the same continent. We have drawn the same conclusion with reference to the red soils from the vicinity of Salamanca in Spain.

With this brief statement we shall dismiss the consideration of the red colored soils of the dry steppes and turn our attention to the true Laterites and the soils more or less closely related to them. A great deal will have to be left for future investigators to clear up but much has already been learned. While we shall direct our attention, in treating of the temperate zones, to the influence of forest and grass vegetation on the soil making processes, in the

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1 F. H. Buchanan, Journey from Madras through Mysore, Canara and Malabar, 1807, 2, 440.

2 On the island of Ceylon the word "Cabook" is used as the equivalent of Laterite.

3 Gürich, Zeitschrift der deutschen geolog. Gesellschaft, 1887, 39, S. 96.

4 Ramann, "Pedologie", 1902, 1.

tropics the influence of an evergreen vegetation on one hand and of Savannas on the other must be considered. Apparently the forests of the tropics, as well as those of the temperate zones, promote an energetic weathering of the rocks, because of the heavy rainfall, while the Savannas suffer long periods of drought. According to Schimper[1] the region of evergreen forests receives at least 70 inches of rainfall per year while the Savannas receive from 35 to 55 inches. Under the influence of these conditions there should be a more rapid decomposition of the rocks under the forests and a greater similarity of the soils to Laterite than could be expected in the Savannas. But such forecasts are not borne out by the facts. In the reports of a great number of investigators and travelers the presence of Laterite in the Savannas and of soils unlike Laterite in the evergreen forests has been clearly proved.

The opinions of investigators on this question are divided. Von Richthofen[1] expresses the opinion that the Laterite in India which at the present time is covered with scrubb trees and grass was in Tertiary time, when its formation was in progress, covered with dense forests. Wohltmann,[2] in discussing the origin of Laterite states that the presence of vegetation during its development is not indispensable. Hans Meyer[3] calls attention to the occurrence, especially in East Aftica, of typical Laterite with porous structure only in areas where no forests exist.

How can these views be brought into harmony? We accept the view of Von Richthofen and believe that Laterite must be considered as the product of the tropical forest,[4] though at present Laterite may be found on Savannas. One should not conclude however, without careful consideration that existing Savannas occupy the position of forests of a former geological period in which Laterite was formed. Such a position should not be accepted as a universal relationship and particular instances should be accepted after full consideration only. Such a change in type of vegetation could take place only under the influence of a change in the distribution of moisture without a change in the other climatic factors. Laterite, as is well known, is very porous. The greater part of the moisture percolates rapidly through the soil and although the amount received by it from rainfall is large, that remaining within reach of plant roots is not sufficient for the normal development of an evergreen forest.

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1 Schimper, Pflanzengeographie, 1898.

1 Von Richthofen, Fuhrer für Forschungsreisende, 1901. See also Zenker, Mitteilungen a.d. deutschen Schutzgebieten 1895, who reports the occurrence of Laterite everywhere under dense forests and DuBois, Tscherm. min. und petrog. Mitteilungen, 12, Heft 1, 1903.

2 Wohltmann, Die naturlichen Factoren der tropischen Agrikultur, 1892.

3 H. Meyer, Der Kilimandjaro, Berlin, 1900.

4 We do not deny the possibility of Laterite development in Savannas also but think that the rate of development is slower than in forests.

The existence of plant formations determined not by the nature of the climate where they grow but by the composition of the soil, has long been known to plant geographers. Tippenhauer mentions cases where porosity and penetrability of the rock to water caused the development of a grass vegetation, in a region where the atmospheric moisture was sufficient for the development of an evergreen forest. Certain regions of East Africa which, at present, are covered mainly by Savannas with forested islands lying here and there were perhaps at an earlier age covered with forest, which became extinct and were replaced by Savannas. The beetles of the African Savannas, according to Kolbe,[1] are nothing more than a remnant of a forest fauna which probably had lived under a cooler and more moist climate. He believed that the forest islands of East Africa are remnants of a continuous forest that existed during the Glacial period. H. Meyer and Passarge both speak of climatic changes in tropical Africa. Undoubtedly the processes of Laterite development in many tropical regions and especially where old crystalline rocks have never been covered by later deposits, are very old. The soil type has never changed because the conditions of soil formation have never changed.

That Laterite changes with a change of the conditions that produced it is shown by many occurrences. According to Passarge[1] no secondary or redeposited Laterite exists in Adamaua, because during transportation it changes to an ashy gray loam.

Laterite can, apparently, change to Podsol or to soils developed under conditions of excessive moisture. DuBois calls attention to the bleaching of Laterite under the influence of humus and plant roots. Moor and Podsol soils which have developed on a Laterite mass differ fundamentally in their chemical characteristics, however, from analogous types of the temperate zone.

Another question which has been answered in different ways by different investigators, concerns the parent rock of Laterite. One group of investigators maintains that Laterite can be developed from every kind of rock, another group does not agree with this view. "It seems," says Von Richthofen[2] "that, under favorable conditions in the tropics, most of the rocks rich in aluminum silicates can change to Laterite." He calls attention to the origin of Laterite from gneiss in India, Brazil and Ceylon. Near Pungo Andongo and Travancore red soil has been developed from sandstone and in the vicinity of Goa, from Basalt. Laterite from granite, diabase,

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1 Kolbe, Ueber die Entstehung der zoogeogr. Regionen auf dem Kontinent Afrika. Naturwissensch. Wochensch., 1901. Neue Folge, 1, Nr. 13. See Richthofen, China 2, S. 734. Anmarkungen.

1 Passarge, Adamaua. Ber. ueber die Expedition des deutschen Kamerun Komitees. Berlin 1895.

2 Richthofen, Führer fürForschungsreisende, 1901.

diorite, and serpentine is known to exist. According to Von Richthofen Laterite may be developed from alluvial and eolian deposits also, Passarge maintains on the other hand that, in Adamaua, Laterite does not exist everywhere but is found everlying such rocks as basalt, green schists, phyllites, and amphibolites only. In addition to these certain red gneisses, granite, quartzporphory and certain sandstones decompose into good Laterite but not the scaly gneiss of Adumre. Passarge designates certain rocks therefore as capable of producing Laterite and certain others not capable. Similar observations have been made by Holdefleisz.[1] He states further that the neovolcanic rocks of the tropics develop into red soils but not into true Laterites. They differ from the latter in their content of both lime and magnesian silicates, which make them productive.

On this matter therefore the views of Von Richthofen are in my opinion correct. Various stages of soil development seem to be represented in the soils of the Laterite group as is the case in the better known Podsol group. Just as we find, in the forest zone of temperate latitudes, various stages of Podsol development represented for the same reason we may find in the tropics, in addition to typical Laterite representing the last stage in the operation of the soil forming processes, representatives of various other phases[2] of the operation of the same forces. The energy of the Podsolizing process depends on the relief, moisture, the character of the rock and the vegetation. The energy of the Lateritizing process depends likewise on all these forces, and also, as has already been mentioned, on the age of the process. When we state that Laterite may be formed on every kind of rock we must recognize that certain exceptions must be made. Pure quartz sandstone, for example, is not adapted to its formation, but such rocks are of very rare occurrence. Most sands, as well as sandstones contain considerable quantities of silicates and aluminum silicates. Perhaps certain varieties of marl will not produce Laterite in the early stages of their decomposition because of the strong influence of their chemical characteristics, but when decomposition has gone further their decomposition products will change into Laterite, on account of the fact that these rocks contain a certain amount of aluminum silicates which can decompose into the same kind of material as the silicates of granite, diorite, and other rocks. Sapper,[3] in fact, reports the occurrence of Laterite on marly rocks in Central America.

Before we take up the description of the structure and composition of Laterite we shall discuss the importance of climatic influences in its development. These soils underlie large areas of the earth's surface and are considered characteristic of the tropics,

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1 Holdefleisz, Die Bodenbildung in den Tropen. Keilhak's Geolog. Zentralblatt, 2 No. 16, S. 486.

2 Vageler has recently expressed the same opinion in Fühlings landw. Zeitschrift, 59, 1910, Heft. 24.

3 Sapper, Ueber Gebirgsbau und Boden des Nordl, Mittelamerika. Peterm. Mitteil. Erganzungsheft, No. 127, 1899.

that is, regions of high annual temperature and high precipitation. One may expect to find Laterite-like soils outside the tropics where climatic conditions, like those in the tropics, exist[1]. It remains yet to be shown that such occurrences outside the tropics are not in fact fossil soils which were developed as Laterites under tropical conditions and owing to a recent change of climate have not had time to adjust themselves to the new conditions. Such soils will be discussed later.

The above described climatic conditions favor the rapid decomposition of the organic matter of the soil, often resulting in its complete mineralization, and the prevention of its accumulation in the soil. In the tropics even large tree trunks decompose rapidly and give up to the soil their inorganic material. It is unnecessary to do more in this connection, than merely to mention grass vegetation for it does not exist. Richthofen, Dafert and Wohltmann all note the very small amount of humus in the soil.

The lack of humus or the existence of an extremely small amount of it, is one of the characteristics of Laterite soils. We must here explain that the term humus as used in this book refers to those organic substances which are combined with the inorganic constituents of the soil and not to a cover of half decomposed organic remains which often overlies the soil in virgin forests as a layer of considerable thickness. This layer decomposes rapidly after the removal of the forest without increasing the amount of humus actually in the soil as an essential constituent.

The decomposition and disintegration of the organic matter in the tropics as well as in other latitudes is effected wholly or partly through the activity of many organisms, their activity in the tropics seemingly being of especial intensity. According to the work of Keller[2] the activity of earthworms is, in the tropics, very important, one species, Geophagus Darwinii, a Madagascar worm attaining a length of more than three feet and a diameter of more than three quarters of an inch. Within a half hour's time such a worm will discharge 100 grams of moist earth from its body. The excrement of worms often especially well preserved in the dense virgin forests, will often weight from 130 to 150 grams. Excrement of 300 grams or more have been observed. The "thousand leg" Julus corallinus of the island of Reunion consumes the fallen leaves and branches in extremely large quantities. No less important is the work of the ants which destroy tree trunks and reduce them to fine powder. Jhering[3] reports as follows on their work: "In the region

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1 Such are known to exist. Schenk (Peterm, Mitt. 1880) describes the occurrence of Laterite in Cape Colony, The Trasvaal and Natal, though there is some doubt about the accuracy of his diagnosis, Von Richthofen cites the occurrence of buried Laterite in Asia.

2 C. Keller, Reisebilder aus Ostafrika und Madagaskar. Leipzig, 1887.

3 Jhering, Ueber Schichtenbildung durch Ameisen. Neues Jahrbuch für Min. 1882. I. Briefl. Mitt. S. 156-157.

of Rio Sinos, Brazil where, usually, red clay underlies surface sand, clay covers the sand locally to the thickness of four or five inches. The upper clay layer has been brought up from the lower clay and laid on the surface by the Termite Atta cephalotes."

Intensity of chemical weathering which has caused the development of laterite of uniform characteristics from the most diverse rocks, is closely associated with the extraordinary energy of the decomposition of organic matter. It is so strong that Laterite, essentially uniform in character, has been developed from rocks that vary widely in character. The similarity of appearance of the Laterite which has developed from various rocks can be explained when we bear in mind that the rocks are composed mainly of silicates of iron and aluminum. Although these minerals are different their products of weathering, especially the end products, are similar.

According to the descriptions of Von Richthofen and Pechuel-Loesche and others, Laterite in fresh condition consists of a hard, though sectile mass, usually loamy, often however sandy, of brown, yellow, red, or white color. The light colored and white parts are soft and on that account are washed out of the mass in exposed places. This gives an exposed surface a honey combed or cellular character. The harder and darker colored parts of the soil are high in their content of iron. In places these parts have a glistening appearance, are brown or black in color, and hard, giving the profile a slag like appearance. Such crusts ring like hollow bodies and are easily mistaken for the products of volcanic eruption with which they, of course, have nothing in common. In powdered condition the material is red. This characteristic is mentioned here with especial emphasis, because we shall make use of it later in discussing the character of the iron hydroxide in Laterite. The per cent of metallic iron present varies from 25 to 36. On this account the soil is utilized in places, especially in Africa, as iron ore. The thickness of the soil layer is often very great, reaching a maximum of tens and occasionally of hundreds of feet according to Von Richthofen. The gradual change from crystalline rock to Laterite can often be seen in deep exposures.

The following description of a vertical section of Laterite is from Von Richthofen[1]:-

On the surface the Laterite is cellular, rich in iron and carmine or brown in color. In the cells which are formed of a hard iron crust, lies a soft powdery or loose mass that is easily washed out by rain.

1. Dark red laterite of uniform character filled with hard brown iron crusts. Thickness 1 meter.

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[1] F. von Richthofen, Zeitschrift der deutchen geologischen Gesellschaft, 1860.

2. Soft loose material rich in iron. The outer surfaces of the particles are reddish. The center is ocher yellow. 3 meters.

3. Reddish compact material with yellowish streak. 1 meter.

4. Yellow material with whitish streak. 1 meter.

5. Yellowish material containing grains of quartz, with incipient cracks. 1 meter.

6. Slightly weathered gneiss. The surface fractures expose Kaolinized feldspar. 1 meter.

The gradual transition from the yellowish and yellow material in the lower horizons to the red color of the upper is well shown in this profile and is characteristic. It is well known that the highly hydrous iron oxides are recognized by their yellow color while those with the lowest content of water are red in color. At present we shall not discuss the form of hydrated iron present but will merely remark that the transition from the form with high water content to that with low water content as one rises toward the surface is explained by the fact that the surface horizons of the soil are heated and dehydrated while the temperature of the horizons lying a few meters beneath the surface is lower so that no dehydration takes place in them.

Laterites contain not simply crusts of hydrated iron oxide but aggregations of crusts and round concretions as well as important quantities of the oxide of manganese. Newbold[1] found veins and aggregations of manganese compounds in the Laterites of the Dekkan plateau. The content of iron decreases with depth as is shown in the following table from Blanford[3].

Depth	Iron Content
About 1 meter	24.5%
" 2.5 "	18.7"
" 4 "	15.3"
" 5 "	16.1"
" 6.5 "	10.0"
" 8 "	8.3"
" 9 "	4.8"
" 10 "	4.0"
" 13 "	3.8"

According to Oldham[4] the content of iron in the Laterite of the Dekkan decreases from place to place as follows:

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1 Newbold. Journal of the Asiatic Society of Bengal XIII, 992, 188.

2 See also, Mallet, Records Geol. Surv. of India No. 1, and Posewitz, Peterm. Mitteilungen, 1887, S 20-25.

3 Blanford, Memoirs of the Geological Survey of India, I, page 241, 271..

4 Oldham. A Manual of the Geology of India, 2nd Edition.

		Fe	Fe_2O_3
1.	Amarkantak	35.6	50.8
2.	Kóthiáwar (Western India)	22.8	32.5
3.	Máin Pát, Sarguja	16.6	23.7
4.	Kaláhandi south of Sambalpur	15.0	21.4

Some varieties of Laterite contain hydrated iron oxide in the form of tubes which penetrate the soil in crooked courses in all direction, predominantly vertical or nearly so but often horizontal.

In place, or where it was developed, Laterite is free from any bedding or stratification, or such regularity of layers as may be present correspond to those in the underlying rock. Quartz veins which occur in the parent rock continue upward into the laterite and fragments of the parent rock itself are often found. When such fragments are broken they sometimes show that the color of the Laterite persists almost unchanged throughout their mass. Pechuel-Lösche[1] found hard fragments of clay slates in the Laterites of West Africa which had assumed a red color.

The so-called "Red Loams" of sub-tropical latitudes are related to Laterite, differing from it in the absence of or low content of slag-like or cellular concretions of hydrated iron oxide. These soils are widely distributed over the sub-tropical regions of South America, being found in central Brazil, Uruguay and Paraguay. Like Laterite, the Red Loams are derived from various rocks such as gneiss, granite, diabase, basalt and schists. The climatic conditions of sub-tropical latitudes under the influence of which the incomplete or first stages only of Laterite development takes place were considered by Wohltmann[2] as the cause of the absence of Laterite and of its replacement by the Red Loam. Apparently the red colored soils carrying little or no hydrated iron oxide in the form of concretions constitute a series of intermediate forms between true Red Loam and true Laterite. Such intermediate forms were studied by Sapper[3] in Central America.

It was shown on a preceding page that the deeper horizons of typical Laterite contained few concretions, or none at all, even where the color was like that of the surface. Since these deeper horizons, as compared with the upper, represent material in a less advanced stage of rock decomposition they can to a certain extent be compared with the Red Loam.

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1 Pechuel-Lösche. Westafrikanische Laterite. "Ausland" No. 21 & 22.

2 Wohltmann, Die naturlichen Faktoren der tropischen Agrikultur 1892. See also W. Koert, Zeitschrift d. deutschen geolog. Gesellschaft, 56, 1904.

3 Sapper, Petermanns Mitteilungen, Ergänzungsheft No. 127, 1899.

In Laterite regions secondary deposits of the soil are formed. The lighter parts are eroded, carried away and redeposited in the low lands. Such deposits are usually designated as secondary Laterite.[1]

If the same conditions exist in a region of secondary Laterite formation that existed in the region where the material originated the processes of Laterite formation continue to act and the surface of the deposits becomes true Laterite. As we shall see later such deposits differ from primary Laterite in chemical composition. They may contain few hydrated iron oxide concretions or none at all and in consequence of this it is like Red Loam in external characteristics. For this reason it is difficult to distinguish Laterite from Red Loam in tropical and sub-tropical latitudes, at least by external appearances only.

Red Loam and Laterite are not always deep red in color. According to the reports on the soils of Brazil[2] and of Madagascar[3] and according also to the samples which I have studied myself,[4] the soils of these regions fall into four groups according to color; red, yellow, violet and white. It has not yet been determined whether the soils of the last group are true soils or are mere soil derivatives. It is possible that in the process of erosion the heavier ferruginous portion of the soil is separated from the white portion and deposited in a different place. It is also possible that the white soil is the weathered product of rocks low in content of iron. We have samples of old soils of the same type from the coast region which will be described below. These old products of weathering have been derived from basalt lava in which the total iron content is in the form of magnetite. Since the magnetite has remained almost completely unaffected by weathering the soil therefore must remain white.

In Brazil, the following characteristic terminology is used in designating the several varieties of soils:

1.	Terra Cantaduva	-	Ferruginous clayey soil.
2.	" roxa	-	Clayey soil more ferruginous.
3.	" superior	-	Highly ferruginous sandy loam.
4.	" igual	-	" " loam.
5.	" branca	-	White soil.

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1 In the erosion of Laterite deep narrow gorges with vertical walls are formed much like those formed in loess covered regions.

2 Wohltmann. Die Natürlichen Factoren der tropischen Agrikultur, 1892.

3 Müntz and Rousseau. Etude sur la valeur agricole des terres de Madagascar. Bulletin due Ministere d'Agriculture 1900, No. 5.

4 The samples from Brazil are from Sao Paulo and were received through the courtesy of Dr. E. Hussak.

This terminology shows that in the Red Loam group, as in every genetic group of soils, there are a number of varieties present differing from each other in their mechanical composition. The same is true of the Laterites. There are clayey Laterites, loamy Laterites, Lateritic sandy loam as well as clayey Red Loam, Red Loam, sandy loam, etc.

The following table shows the mechanical composition of the soils of Brazil and Madagascar, taken from the works of Wohltmann, Müntz and Rousseau:-

Brazil

	Coarse grained sand	Medium sand	Fine earth
Terra roxa Limeira	46.9		53.1
" " S. Barbara	9.10	34.4	56.5
" vermelha "	7.30	42.2	50.5
" " "	11.80	33.0	55.2
" arenosa " "	5.80	35.0	59.2
" massape	31.13	20.87	47.12

Madagascar

	Coarse sand. %	Fine sand. %	Silt and Clay %
Red soils	28.12	36.45	34.84
Yellow soils	37.75	45.12	16.64
Violet soils	45.07	50.02	2.74

The chemical composition and other characteristics of Laterite and Red Loam contain many features that are unique. On the basis of morphological features one can postulate that the iron hydroxide in Laterite is different in form from that of the same compound found in the soils of northern Europe. So far as is known to the writer Crosby[1] was the first to call attention to the characteristic composition of the hydrated iron oxide of the Red Loam. He was of the opinion that, under the influence of high temperature the hydrated iron oxide, high in water content, was dehydrated, by which limonite and goethite were changed to turgite and hematite. Russell[2] maintains however that the color of the product of

1 Crosby, Proceeding of the Boston Society of Natural History, 1885.
2 Russell, United States Geological Survey, Bulletin No. 52, 1899.

weathering was closely related to the age of the material. In regions of secular weathering such as the Laterite region, the Red Loam region of Southern Europe and the southern Appalachians in North America, red colors predominate. In glaciated regions, yellows and grays are the predominant colors of the weathered material. The color can not therefore be due to existing climatic conditions alone. The color once established remains, so that quartz grains retain their red colored outer layer even after they are worn to pebbles.

Russell's view cannot be entertained because on the one hand old weathered material without red color is known to exist and on the other hand red products of weathering are often thoroughly bleached or otherwise changed in color with change of external conditions. We cannot undertake to discuss the investigations which have dealt with this matter[1] but we will merely mention that color of tropical soils has been ascribed to hematite by many investigators without sufficient basis of fact.

It has been stated already that the powder of black Laterite crusts is red in color. The analyses of these crusts from Surinam, in the lowland of Guayana, published by DuBois[2] does not determine the character of the hydroxide since it shows, besides iron, several other constituents. The following analyses by the same author, of pisolites from Laterite, allow us to draw a better conclusion.

	1.	2.
Fe_2O_3	83.4	86.9
SiO_2	7.0	3.1
Al_2O_3	5.0	4.0
CaO	1.00	1.0
H_2O	4.00	5.4

These analyses allow us to conclude safely that turgite is present in Laterite and Red Loam, its formation being due to the high temperature to which the upper horizons of the soil are raised in the tropics. In the lower horizons limonite and xanthosiderite occur in considerable amounts.

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1 See Dara, American Journal of Science, Vol. 39, 1890, page 317-319. Katzer, Neues Jahrbuch f. Min. 1899, 2, H. 3 Briefl. Mitt. S. 177. Spring, Neues Jahr. f. Min. 1899, I., S. 47. H. Stremme, Zeitschrift f. prakt. Geol. XVIII, 1910 H. 1. A series of views on this subject may be found in the work by Russell, already cited. References to the literature on weathering are given also.

2 DuBois, Tscherm. min. u. petrog. Mitteil., 12, H. 1, 1903.

Occasionally grains of ilmenite cover the turgite crusts in Red Loams and Laterites. They were noticed on two tropical soil samples by the author, one sample being from Sao Paulo, Brazil, the other from Wollongbar, Australia. A sample of a tropical soil was treated with bromoform in order to dissolve the iron hydroxide and a reddish brown powder was left in the funnel, this being the characteristic color of turgite. When treated with hydrochloric acid this powder lost its color rapidly when heated to the boiling point and a great number of ilmenite grains remained behind. The same mineral was obtained from the red colored soils of the semi-tropical regions of Australia after treating the soil sample with hydrochloric acid and later with caustic potash. Max Bauer[1] states also that the ilmenite of a diabase does not succumb to the weathering forces.

In the following table some analyses of Laterites and Red Loams are given in which the titanic acid has been determined:-

	1 %	2 %	3 %	4 %	5 %	6 %	7 %	8 %
SiO_2	34.81	4.54	24.62	12.6	11.81	7.50	2.01	2.35
TiO_2	4.89	8.99	8.12	3.24	4.50	14.08	6.49	6.61
Al_2O_3	33.18	41.35	23.89	34.71	33.10	0.14	58.23	57.50
Fe_2O_3	23.03	40.87	37.85	22.76	24.47	62.08	5.48	6.53
FeO	2.34	2.52	2.08	1.26	0.61	-	-	-
MnO	0.28	0.08	0.25	-	-	0.09	-	-
CaO	trace	trace	trace	0.63	1.74	0.02	0.45	0.15
MgO	0.39	0.37	0.99	0.16	1.22	-	-	--
K_2O	-	-	-	0.32	0.35	-	-	-
Na_2O	trace	trace	0.41	0.14	-	-	-	-
Loss on Ignition	-	-	-	23.70	23.10	15.60	28.10	26.94

Numbers 1, 2 and 3 are weathered products of the lava of the Hawaian Island which were analyzed by Lyons[2]; 4 and 5 are the products of the weathering of diabase;[3] 6 is an iron crust from Surinam reported by DuBois; 7 and 8 are Indian Laterites from

[1] Max Bauer, Neues Jahrb. f. Min., 1898, II, H. 3.

[2] Lyons, American Journal of Science, 152, 1896.

[3] J. Chautard et P. Lemoine, Comptes rendus Academie de Sciences, 1908, p. 239 f.

Surguja and Rewah.[1] The ferrous iron oxide which is given in the first five analyses belongs in the ilmenite.

These analyses show certain other typical features of sub-tropical soils. As is shown by numbers 2, 7 and 8, Laterite contains at times only very small amounts of silica. In the other five analyses the content of silica is relatively unimportant, but sesquioxides are present in large quantities. It appears that those Laterites which were derived from quartz free or nearly quartz free rocks are lowest in silica. Laterite however which has been derived from one of the acid rocks contains a high percentage of silica. The following analyses of soils from diorite and granite by Max Bauer[2] make this clear:

	Laterite from Diorite	Laterite from Granite
SiO_2	3.88%	52.06%
Al_2O_3	49.89"	29.49"
Fe_2O_3	20.11"	4.64"
CaO	-	trace
H_2O	25.98"	14.4"

The analyses show that in the process of Lateritization the silica occurring in the form of the silicates and aluminum silicates, disappears while that occurring in the form of quartz remains. The leaching out of the silica is especially characteristic of the later phases of Laterite development and is scarcely noticeable in the early phases as is shown by the following analyses of a diabase and of its weathered product taken from the work of DuBois:

	Laterite	Diabase
H_2O	8.71%	1.72%
SiO_2	trace	3.10"
Al_2O_3	19.32"	12.23"
Fe_2O_3) FeO)	27.57"	9.25" 8.95"

[1] H. and F. J. Warth, Composition of Indian Laterite. Geological Magazine (4) 10, pp 154-159, 1903.

[2] Neues Jahrbuch für Miner., 1898, II, H. 3.

	Laterite	Diabase
MnO	0.72%	1.10%
CaO	-	8.50"
MgO	trace	4.93"
$Na_2O + K_2O$	-	3.94"

From these analyses it is evident that Laterite contains free aluminum hydroxide. This is present also in other soils as has been shown by Hilgard[1] but in small quantities, and in order to detect its presence it is necessary to examine the fine grained part of the soil. In Laterites on the other hand these hydroxides are present in large quantities and form in places characteristic concretions. They were first described, so far as our knowledge goes, in 1863 by Hermann[2] who discovered them in secondary Laterite from Brazil. They consisted of hydrargillite concretions, about the size of nuts cemented with iron ore, According to Lenz[3] who analyzed iron concretions of Laterite, 85.82 per cent was soluble in hydrochloric acid. The composition of the dissolved portion is shown in the following:

Al_2O_3	12.40%
Fe_2O_3	58.02"
H_2O at 100°C	2.45"
H_2O on ignition	12.95"

The undissolved portion consisted of

SiO_2	10.42"
Al_2O_3	5.40"

The substance consisted therefore of hydrated iron oxide, aluminum hydroxide and aluminum silicate. Wohltmann[4] also mentions the occurrence of aluminum hydroxide in Laterites. Thorough investigations in this respect were made of the Laterites of the Seychelles Islands by Max Bauer.[5] His analyses have already been given (page 97). He treated the soil with hydrochloric acid and determined the amount of soluble sesquioxides, the following table showing the composition of the dissolved portion.

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1 Hilgard. Agricultural Science, Vol. Iv No. 4.

2 Hermann, Journal für Praktische Chemie I, 1869.

3 Lenz. Verhandlung der K. K. Geol. Landesanst. Wien. 1878 S. 350 f.

4 Wohltmann. Die naturl. Fact. der tropischen Agric. 1892. See also Sitzungsber. niederrhein. Ges. f. Nat. und Heilkunde. Bonn 1895 u. 1896.

5 Max Bauer. Neues Jahrbuch für Mineral, 1898, II, H. 3, S. 163-219.

	Laterite from Granite	Laterite from Diorite
Al_2O_3	60.68%	51.98%
Fe_2O_3	9.56"	20.95"
H_2O	29.76"	27.07"

In sandy Laterite the same investigator found

Al_2O_3	76.67%
H_2O	23.33"

On the basis of these results he concluded that the mass of the Laterite containing aluminum oxide consisted mainly of hydrargillite.

In determining the content of aluminum hydroxide in the soils of Madagascar, Schlössing[3] used the following method: Five grams of the soil were treated with a dilute solution of sodium hydroxide containing 3.5 grams Na_2O in a liter of water and boiled for half an hour. The amount of alumina and silica in the filtrate was as follows:

	Al_2O_3	SiO_2
Soil No. 1.	11.72%	1.61%
" " 2.	8.10"	1.92"
" " 3.	6.59"	5.15"
" " 4.	4.69"	5.05"
" " 5.	11.40"	0.94"
" " 6.	3.56"	4.80"

The amount of alumina is considerably larger than that of the silica thus indicating the presence of aluminum hydroxide in the soils. At the same time it is shown that the content of this hydroxide is by no means always large. Soils 4 and 6 contain very little free hydroxide. The reason for this is as yet unknown, though it can be explained in various ways. In the first place the soils may not have all reached the same stage of advance in weathering; in the second place, the various aluminum silicates do not hydrolize at the same rate and in the third place, the inequality in the content of aluminum hydroxide may be influenced by the kind of Laterite; primary Laterite probably containing more than secondary. This is at least the view held by DuBois. According to the

3 Schlössing. Comptes rendus, T. CXXXII, No. 20.

latter author the silica in primary Laterite may be combined with iron. In the deeper horizons of primary Laterite, derived from diabase, the analysis of which has already been given he found by mechanical analysis only 2.5 per cent of quartz sand. This led him to the conclusion that the greater part of the silica was present in combined form. In the same work by this investigator two analyses of secondary Laterite gave the following results:

	1	2
SiO_2	58.03%	57.68%
Al_2O_3	24.04"	22.73"
Fe_2O_3	8.19"	8.98"
CaO	0.59"	-
MgO	trace	trace
H_2O	9.45"	10.60"

In these Laterites DuBois states that as much as 52 per cent of quartz is present. From this it follows that the greater part of the alumina must exist in the form of a hydroxide. An analysis of the concretions of aluminum hydroxide gave DuBois the following:

	1	2	3
Al_2O_3	63.3%	48.5%	55.5%
Fe_2O_3	10.5"	21.6"	14.4"
SiO_2	7.0"	14.5"	3.1"
CaO	1.0"	1.0"	1.5"
MgO	-	-	trace
H_2O	17.6"	14.0"	27.6"

With respect to this matter it should not be forgotten that Laterite may contain, in addition to the hydroxides, a considerable amount of clay. van Bemmelen[1], H. and F. J. Warth[2], found large amounts of kaolin together with hydrargillite and diaspore at various places in Laterite in India. At a later date Max Bauer[3], Atterberg[4], and Mohr[5] verified these results.

1 J. van Bemmelen. Zeitschrift für anorg. Chemie. 42, 1904, S, 265-324.
2 H. and F. J. Warth, Geological Mag. (4), 10, 1903.
3 Max Bauer, Neues Jahrb. für Min., Festband, 1907. 4 Atterberg, Centralblatt für Mineralogie 1909, Nr. 12.
5 E. C. Jul. Mohr. Bull. du Department de l'agriculture aux Indes neerlandaises, No. XXVIII, Buitenzorg, 1909.

We shall give M. Bauer's results obtained from a study of the Laterite of Madagascar. In that at St. Marie, derived from Diabase, he found 37 per cent of hydrargillite and 42 per cent of clay like aluminum silicate. In another sample from the same place he found 47 per cent of hydrargillite and 17 per cent of aluminum silicate. In the first sample the augite was less thoroughly decomposed than the feldspar.

In Laterite at St. Marie, derived from amphibolite there is 64 per cent of hydrargillite and 18 per cent of aluminum silicate. Treated with hydrochloric acid these samples gave the following:

	1	2	3
Insol. Res.	3.78%	4.25%	15.79%
SiO_2	14.17"	6.36"	6.98"
Al_2O_3	44.87"	35.25"	42.37"
Fe_2O_3	17.33"	29.34"	13.04"
CaO	0.18"	0.19"	0.03"
MgO	0.13"	0.37"	trace
H_2O	20.16"	24.31"	21.78"

Red Loam, regarded as a phase of incomplete lateritization, is richer in clay-like aluminum silicates than Laterite by which one may possibly arrive at the conclusion that the formation of free hydrated aluminum oxide is the product of the lateritization process at a late stage of its operation, following the hydrolysis of the aluminum silicates of the alkalies and alkaline earths. This question must be further studied however.

In closing this discussion of the chemical composition of Laterite and Red Loam, we must call attention to the obvious fact, as shown by the analyses, that the alkalies and alkaline earths are present in very small quantities, Lime is often entirely lacking and when it is present at all the quantity is smaller than that of magnesia. The same is true of sodium. It is either absent entirely or is present in small quantity, smaller even than that of lime. This is well shown by the following analyses of soils from Madagascar:-

	Red Soils %			Yellow Soils %		Violet Soils %	White Soils %
SiO_2	57.0	57.6	51.7	29.6	52.1	67.6	63.6
Al_2O_3	32.9	29.6	35.8	35.0	30.0	34.5	24.3
Fe_2O_3	9.2	11.4	11.3	34.3	16.9	5.7	0.1
CaO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MgO	0.7	0.8	1.7	0.9	0.7	1.5	1.9
K_2O	0.1	0.6	0.2	0.2	1.3	0.7	0.2
Na_2O	tr.	tr.	tr.	tr.	tr.	tr.	tr.

Taking into consideration the total quantity of accumulated knowledge of Laterites and Red Loams we seem to be justified in considering them as soils from which the alkalies and alkaline earths and the silica of the silicates has been removed and in which argillaceous aluminum silicates and to a greater or less extent hydrated sesquioxides have accumulated. This is the result of an energetic hydrolysis of the minerals due to the high temperature and the presence of carbonic dioxide resulting from the decomposition of organic matter. The influence of temperature is very important. It never sinks below the freezing point so that weathering is active throughout the whole year. Through the hydrolytic action and the formation of carbonates in the presence of organic matter the carbonates of the bases pass into solution in the soil water. These dissolved carbonates themselves act on the undecomposed mineral material through the series of complex reactions. It is possible that the mobility of the aluminum hydroxide and the formation of concretions of hydrargillite is effected partly through the aid of alkaline carbonates.

The Terra Rossas of southern Europe and of the southern part of North America have been investigated to a less extent. The term Terra Rossa has long been applied to these soils in Europe but their origin must be regarded as not yet entirely cleared up in spite of a series of investigations that have been concerned with them. We will consider briefly how various investigators have answered the question as to their origin. According to Neumayr[1] the distribution of the Terra Rossas of southern Europe is very closely related to that of limestones; that no single occurrence is known where this relation does not exist. Secondary deposits only are found without

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[1] Neumayr, Verhandl. d.k.k. geol. Reichsanst. Wien, 1875, S. 50-51

any close relation to limestone. The Terra Rossa of Istria and Dalmatia, which lies on sandstones is considered secondary by Neumayr. This investigator thought that the deposit was closely related to the red clay of the deep sea which is formed by the decomposition of the calcareous shells of the Globigerina ooze. He compared this process with the weathering of limestone on the earth's surface which has been formed from the Globigerina or a similar ooze.

Neumayr treated 77.76 grams of the Karst limestones with acetic acid and obtained .044 per cent of the red substance which contained almost 20 per cent of Fe_2O_3[1]. The presence of the red substance in the limestones makes the solution of the question difficult to a certain degree but the conclusion of Neumayr can hardly be considered as generally applicable.

Fuchs[2] called attention to the occurrence of Terra Rossa in Greece, Italy and the Karst where it has been derived from limestone not of marine origin, and denies the similarity of Terra Rossa and the red deep sea clay. At the same time he states that he has always found the Terra Rossa developed only on white, dense and pure limestones and never on marly, chalky, dark or gray limestone. He states also that Terra Rossa originates only on the limestones of southern Europe, while neither the Silurian limestones of Bohemia nor the various palaeozoic and mesozoic limestones of northern France, Belgium and England are overlaid by this material. He ascribes the formation of this soil therefore to climatic factors. He maintains that Terra Rossa can originate only in places where the climate is dry, vegetation sparse and in places therefore where no humus accumulates. The last conclusion however can hardly be accepted. In the coastal belts of the Mediterranean and Adriatic seas there is a total rainfall in many places amounting to as much as 40 inches and always as much as 20 inches. In Italy it reaches 30 inches. Although this climate may be considered as a little too dry for a luxuriant vegetation, yet it may be sufficiently moist for the weathering processes. The total rainfall for the year is not the most important factor for the vegetation, its distribution through the year being much more important.[3] The coastal zones of southern Europe, as is well known, lie within the region of high winter rainfall. The summers only are dry. Such a distribution of rainfall influences vegetation and causes the development of trees with leathery leaves.[4] In general however there is sufficient rainfall

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[1] Lorenz calls attention to the presence of a red substance in the Karst limestones ranging in amount from 2 to 23 per cent in one variety and from 6 to 13 per cent in another. Verhandl. d.k.k. geol. Reichsanstalt, Wien. 1881, S. 81-82. The Red Loams (Terra Rossas) derived from limestones contain 70 to 80 per cent of Fe_2O_3 and Al_2O_3.

[2] Fuchs. Verhandlungen der k.k. geol. Reichsanstalt, Wien. 1875, S. 194-196.

[3] Herbertson. The Distribution of Rainfall over the Land. London, 1901

[4] Schimper. Pflanzengeographie, 1898, S. 547.

for the weathering processes so that in this sense the region cannot be considered as a dry one.

The observations of Stache[1] are especially noteworthy. He states that the older deposits of the Terra Rossa of southernIstria often contain indurated portions which consist of laminated red argillaceous material with small grains of iron ore and small pisolitic concretions rich in alumina. In the redeposited Terra Rossa of northern Istria and Krain, Stache in addition to the iron ore grains, found fragments of limonite crusts of various kinds. Such information enables us to compare these Terra Rossas of southern Europe with the bauxites of Wochein. These observations are interesting because they could very well raise again the question of the relationship of Terra Rossa to Laterite. A close relationship has been accepted by some investigators. Stache however arrives at a different conclusion.

In recent years the Terra Rossa of Istria has been described by Graf. zu Leiningen[2] who postulates that the plant cover consisting of heath and various moist land plants, acts only on the surface of the soil. Under the Calluna vulgaris, Erica cornea and other plants no humus accumulation takes place but the red color of the soil changes to a reddish brown or brown. The color of the soil is influenced to a very slight extent by the vegetation of forests and of "Maquis". The Terra Rossas of Istria are very fine grained and contain as much as 84.4 silt and clay and on this account are very high in their water holding capacity and not easily penetrable to water.

Graf zu Leiningen publishes the following analysis of a Terra Rossa sample which was collected between Abbazia and Lovrana:

H_2O and organic matter	11.77%
SiO_2	47.78"
Fe_2O_3	32.24"
Al_2O_3	3.15"
Mn_3O_4	1.35"
CaO	0.68"
MgO	1.37"

1 Stache. Verhandlungen der k.k. geol. Reichsnst. 1886, S. 61-65, 385-387
2 Graf. zu Leiningen. Naturwis. Zeitschr. fur Forst und Landwirtschaft, 9, Jahrgang, 1911, Heften 1 und 2.

K_2O	1.15%
Na_2O	1.56"
P_2O_5	0.23"
CO_2	0.20"

The Terra Rossa of Rumania has been briefly described by Munteanu-Murgoci.[1] Treitz,[2] in a recent paper, lays considerable stress on the close relationship of the European Terra Rossa to Laterite.

In discussing the formation of Terra Rossa it should not be forgotten that this soil, as it occurs in southern Europe, represents, in many cases, a product of weathering which was formed during Tertiary time and which in recent times has been disturbed and had its unity destroyed in places by erosion, transportation and redeposition. I have seen such phenomena in the vicinity of Bikszad in Hungary. At this locality the Tertiary Terra Rossa derived from Augite andesite is, in places, still in place. We shall refer to this occurrence again in the discussion of fossil soils.

It is possible that the origin of the east Hungarian[3] and Italian[4] bauxites is connected with the processes of weathering. For that reason the question of the formation of Terra Rossa in southern Europe is made difficult. It will be necessary to study the soil systematically in the greatest number of localities possible. Soils similar to the European Terra-Rossa are found in the southeastern part of North America and on the neighboring Bermuda Islands. The red soils of the United States are described by Russel in a paper already mentioned (p) and of New Guinea by W. Meigen.[5]

The brownish yellow and reddish yellow soils of southern Europe may be considered as transition soils between the soils formed under Optimum moisture conditions and those formed under medium moisture conditions. They seem to be widely distributed in southern France. We shall designate them for the present by the name yellow soils, a term possibly not perfectly applicable. According to my

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1 G. Munteanu-Murgoci. Comptes rendus de la premiere conference international agrogeologique. Budapest, 1909.

2 Treitz, Die Aufgaben der Agrogeology. Földtani Közlöny, XII, H. 7-8, 1910. See also Sandor, Verhandl. des zweiten internationalen Agrogeologen-Konferenz, Stockholm, 1911. Murgoci, Ibidem, S. 329.

3 Lachmann, Zeitschrift fur prakt. Geol. 1908, S. 353, 362 und 504-505.

4 Stelzner-Bergeat, Die Erzlagerstätten, 1905-06. II S. 1242 f. und auch Lotti, Zeitschrift fur prakt. Geo. 1908, H. 12, S. 501-502.

5 Meigen, Zeitscrift der deutschen geolog. Gesells. 57, Heft. IV, Briefl. M., S. 557-564.

interpretation the Hungarian "Nyirok"[1] also belongs in this group. They are derived from a variety of rocks including limestones, a fact observed by me on the road from Paris to Bordeaux, on the Spanish boundary further south and on the way to Lyons.

An important content of ferric iron and a small content of humus, if one judges by the color of the surface horizon, make the yellow soils like the Terra Rossas. At the same time they seem to have something in common with the soils of medium moisture conditions. According to the studies of Bogoslowski[2] a translocation of the sesquioxides has taken place in them. He describes a profile of these soils at Rives station between Grenoble and Lyons as follows:

1. Reddish yellow clayey horizon with pebbles, 0.2 meters.

2. Reddish brown loamy, gravelly, loose, horizon without efflorescence.

3. Stratified deposit of pebbles of gray color.

The soils of this group are apparently widely distributed in Japan and France, two countries where they could be properly investigated. In both countries the soils of the true continental zones are absent entirely and on that account one can follow all transitions from the Podsol soils to those of the true Terra Rossas.

The references to the most important literature in addition to that already cited will be found in a paper by Du Bois, in Tschmaks miner. und petrog. Mitteilungen, 12, H. 1, 1903 and in a paper by Max Bauer in Neues Jahrbuch für Mineralogie, 1907, Festband.

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1 P. Treitz, Földtani-Közlöny XII, H. 7-8, 1910.

2 Bogoslowski, Pedologie, 1902, No. 4, p. 365 (Russian).

II. SOILS DEVELOPED UNDER MEDIUM MOISTURE CONDITIONS

The most important group in this class is that of the Podsol soils. In the forested regions of northern Europe and European Russia, in northern Asia and North America, these soils form an unbroken zone. On the basis of climatic and botanical conditions they should be expected to occur, as has already been mentioned, in the southern hemisphere also, in the most southerly part of South America, sporadically also in other parts of the earth, within other soil zones where a favorable combination of soil forming factors occurs.

The genesis of the Podsol soils is thought to stand in intimate relation with the existence of forests, because the greater part of these soils are characteristic of forested regions, although Podsol development is known to have taken place without the influence of forest vegetation. Many years ago Kindler[1] called attention to the bleached condition of sands under conifer forests. Daubree[2] also mentioned the occurrence of such phenomena associated with plant roots in the Rhine lowland and in Lorraine. Similar soils were described by Sprengel[3] in 1837.

Because of the white or gray color of these soils the Russian people, since ancient times have called them Podsols, soils which are like ashes, derived from the Russian word Sola meaning ashes. The ashy gray color is a characteristic feature of these soils.

Of recent west European investigators who have investigated the Podsol soils Emeiss[4], Emmerling and Loges[5], P. E. Müller[6], Ramann[7], A. Mayer[8], and Münst[9], should be mentioned. They have confined their studies mainly to those varieties of Podsol soils that are accompanied by hardpan, yet they have described Podsol profiles in which the hardpan is only faintly developed or not developed at all. Especially good illustrations of the Podsol profile have been published by Emeis, P. E. Müller and Ramann.

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1 Kindler, Poggend. Annal. 1836, XXXVII, 203 - 206.
2 Daubree, Compt. rendus Acad. des sc. XX, p. 1775 - 1780.
3 Sprengel, Die Bodenkunde usw., Leipsig, 1837.
4 C. Emeiss, Waldbauliche Forschungen und Betrachtung, Berlin, 1876.
5 Emmerling and Loges, Vereinsblatt der Heide-Kultur Verein für Schleswig-Holstein, 1886, S. 63-70.
6 P. E. Müller, Studien ueber de naturlichen Humusformen und deren Einwirkung auf Vegetation und Böden, Berlin, 1887.
7 E. Ramann, Jahrbuch der K. preuss. Geolog. Landesaust. fur 1885. Berlin, 1886.; Zeitschrift fur Forst und Jagdwesen, 1886, 1, Heft; Die Waldstreu und ihre Bedeutung fur Boden und Wald, Berlin 1890.
8 A. Mayer, Landw. Versuchstat.
9 Münst, Mitteil, der geol. Abteil. der kgl. würt. staatsl. Landesanstalt, 1910 No. 8.

The following description of a soil profile from a locality between Viborg Krat and Viborg Heath is taken from the work of P. E. Müller referred to above:-

A hill, covered with forest, slopes gently to the adjacent plain, the boundary of the forest lying approximately at the foot of the hill. There is no perceptible difference in elevation between a point on the plain beyond the forest boundary and one in the fores near the boundary. The map shows the slope of the hill to be about 1 foot in 400. The first profile is taken from a point within the forest about 60 feet from the boundary. Under a light cover of trash the soil is dark in color, this passing at about 10 inches into a faint reddish horizon about 8 inches thick. Beneath that lies a horizon of sand. This profile is characteristic of the oak forest of this region.

About 60 feet from the boundary on the opposite or unforested side where the vegetation consists of a vigorous growth of heather, and the soil is covered by a dense layer of mosses there is, as in the other case, a surface layer of dark colored soil about 10 inches thick. This is more dense however and harder than the corresponding layer of the above profile and is richer in humus though its middle portion is lighter in color. Beneath this lies again a reddish brown layer 8 inches thick.

Still further from the forest lies a soil in which the humus horizon is three fold: The upper and lower layers are dark in color, the middle, lighter. The average thickness of the whole horizon is 12 inches. Beneath this lies a blackish brown hardpan layer with an uneven lower surface.

Emeis[1] describes similar profiles of heath or Podsol soils.

In the profiles described above the influence of the local relief is noticeable in my opinion. This influence has been carefully investigated in certain Russian studies. Before taking up these studies however I shall quote the descriptions of the sandy and clayey Podsols given by Gieorgiewski[2] for the soils of the Luga district in the province of St. Petersburg.

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[1] Emeis, Waldbauliche Forschungen und Betrachtungen, Berlin, 1876.

[2] Gieorgiewski. Notes on Soil Investigations, Part IV, 1888 (Russian)

Sandy Podsol

Horizon A, Loose stratum of grayish white color 4 to 5 inches thick.

" A_2 Fine quartz sand, snow white in color, 10 inches thick.

" B The hardpan; a more or less dense, in part hard, mass of brown or black color, in places imperfectly cemented grading into brown sand in places. This horizon occurs in continuous strips for considerable stretches and in isolated concretions; its thickness is about 10 inches.

" C Reddish yellow or yellow glacial sand.

Clayey Podsol

Horizon A Whitish gray, fine grained layer, 5 to 6 inches thick.

" A_2 The Podsolized horizon. In its natural moist condition it consists of a dense, somewhat laminated mass, nearly white in color. In dry condition it is still whiter and falls into fine powder, though brown concretions are sometimes present. Thickness 5 to 6 inches.

" B A compact clay mass with numerous dark and brown concretions. The color of the horizon varies, white flecks alternate with red and yellow streaks and veins of the slightly changed parent rock. The thickness is about 8 inches.

" C Compact bowlder clay, reddish brown in color.

On loess-like parent material Podsols have much thicker profiles, with relationships of parts similar to the above.

The following is quoted from Tumin[1]:-

Horizon A Light gray, with dark shade, showing horizontal distribution in layers when broken. Concretions, round in shape and 1 to 2 cm. in diameter, are present in small quantities. The thickness of the whole layer is about 14 centimeters.

" A_2 Whitish, porous horizon with platy structure, the thickness of the layers being about 1 to 2 millimeters. The pores are oval in shape, 1 to 2 millimeters in length and .5 to .75 millimeters in breadth. Iron concretions are present but less abundant than in A_1. Thickness of horizon about 11 centimeters.

1 Tumin, Data for Estimating the Value of the Soil of the Province of Smolensk, Part V. Dorogobush District, Smolensk, 1909 (Russian).

Horizon B Brown with white flecks and streaks, laminated. The amount of white material decreases downward and the layers or strata become less well defined. At a depth of 90 centimeters faint rusty colored spots appear. The white spots may be seen to a depth of 120 centimeters. Iron concretions are very rare.

Horizon C Brown loess-like loam with rust colored spots.

All these profiles of Russian soils belong to the Podsols. This term is used to designate soils which have a pronounced and well developed whitish A_2 horizon. If this horizon is not well developed, and the corresponding horizon contains whitish specks and stringers the soil is said to be Podsolic. If horizon A_2 is absent entirely the soil is said to be faintly Podsolic. All these varieties may develop from one kind of parent material.

Varieties of Podsolic soils exist in which the typical Podsol horizons are hard to find. Special care must be exercised by the observer in order to discover them and to determine their value.

If the Podsolic spots are entirely absent from the upper horizons of the soil, we have no right to maintain that such a soil is not Podsolic, for it often happens that the whitish Podsolic horizon is developed at greater depths and fails entirely in the upper horizons. Soils which develop on sands with clay subsoils or substrata at depths of 1 to 1-1/2 meters are usually of this kind. They are abundant in the morainic deposits of northern Russia.

A second humus horizon is often present in Podsolic soils derived from loess-like rocks with plastic clay at shallow depth. It is however not so well developed as the first. A lower humus horizon becomes less noticeable where the mechanical composition of the soil remains constant downward, as we shall see on taking up for consideration the mechanical data. At a depth of 1 meter or more there appears, in addition to a second humus layer occasionally, an accumulation of manganese peroxide spots. As an example, the profiles of two Podsol soils from the Gshatsk district of Smolensk are here described. A short distance from Upolosy, a village on the Worja river, the soil is developed from a thin loess-like loam deposit overlying bowlder clay. The whole thickness of the loess-like loam is included in the surface humus horizon A_1 and the whitish layer A_2. The latter appears as an unbroken horizon with a thickness of about 5 centimeters. It sends broad, blunt, whitish projections downward into the bowlder clay mass. Immediately over the bowlder clay there is an intermediate layer of black oxide of manganese, with a thickness up to 2 centimeters. On the same river opposite the village Micheewa, the soil has developed on a loess-like loam which has a considerable thickness and is underlaid in the substratum by glacial sand, with very few stones and gravel. Two thin intermediate, undulating layers of clay, lie at different

elevations in this sand. On the upper layer lies an undulating band of material containing lens-like spots of black oxide of manganese. These two examples show that there is a tendency for the oxide of manganese to collect on top of the less penetrable rock layer, which decreases the rate of movement of downward moving solutions.

Other processes by which massive lower humus horizons are formed are often seen. In eastern Siberia[1] where the soil is permanently frozen at no great depth the humus material collects on top of the frozen layer. Such Podsol varieties as those described above usually occur in low places and constitute transition to the moor soils.

Another case of Podsol variation was described from the Amur country by Tomaschewski.[2] Moor soils are here covered in spots by forest, under the influence of which the moor soils gradually change to Podsol soils. At first isolated white spots appear in the middle part of the thick humus layer. These increase in number until an unbroken whitish layer is formed which penetrates the humus layer like a wedge and divides it into an upper and a lower member.

We shall now return to the consideration of the influence of minute local relief on the particular kind of Podsol soil developed. Tumin[3] describes and illustrates the character of the Podsol soils on level places, on gentle slopes and in peaty depressions as shown by the Podsol loam in the province of Smolensk. These various phases and transitions are shown in Fig. 5 which shows the characteristics of horizons A_1 and Ao.

A_1 is a gray horizon, with white streaks and spots, of noticeably platy structure, the thickness of the plates amounting to 1 millimeter. The upper surface of each plate is lighter in color than the lower. The horizon contains few pores and concretions. The horizon Ao, the soil cover, is composed of a peaty layer formed from grass and moss. Horizon B of the peaty depressions consists of light bluish loam spotted or mottled with whitish spots and streaked with brick red. The brick red spots extend to a depth of 55 centimeters, but were seen at no greater depth. The rest of the figure corresponds to the profiles described by Tumin, which have been mentioned already in preceding pages.

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1 M. Filatoff, The work of the botanical and soil expeditions sent out for the investigation of areas in Asiatic Russia which were to be colonized. Part I. Soil Investigation under the direction of K. Glinka, 1908, Part 9, St. Petersburg, 1910. (Russian)

2 Tomaschewski. Vorlaufige Mitteilungen über die Organization and Vollziehung der Boden erforschung in Asiatischen Ruszland in Jahre 1910. St. Petersburg, 1911.

3 Tumin, Data for the valuation of the Soils of Smolensk Part V. 1909. (Russian).

The influence of relief on the Podsolic soil in sandy regions has been studied by Sacharoff[1] at St. Petersburg. A generalized profile of the locality where the investigations were made is shown in figure 6. The soil profiles are shown in figure 7. Some of them were described by him as follows:

Profile No. 4.

Horizon	A_1	The very faintly developed upper humus horizon is dark gray when dry. The upper part consists of half decomposed plant remains. Here and there whitish intermediate layers were noticed. 3 cm.
"	B	Brownish gray layer with gray spots of decomposed substances. 12 cm.
"	B_1	Yellow sand with numerous rust colored spots.

Profile No. 5.

Horizon	Ao	Forest leaves and trash. 2.5 cm.
"	A_1	Humus horizon, compact and somewhat peaty. 1.5 cm.
"	A_2	Ash-gray loose layer without structure. 1 cm.
"	B	Grayish brown, loose. 12 cm.
"	B_1	Rusty yellow, coarse mass. 23 cm.
"	C	Rose gray, coarse deposit.

Profile No. 6.

Horizon	Ao	Forest waste with grass and moss cover. 3 cm.
"	A_1	Grayish black humus horizon. 4 cm.
"	A_2	Ash-gray, structureless and loose. 5 cm.
"	B.	Rather loose dark brown hardpan horizon. 11 cm.
"	B_1	Iron bearing brownish yellow hardpan horizon. 27 cm.
"	C	Cross bedded rose-colored sand.

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1 Sacharoff, "Pedologie", 1910, No. 4. (I have merely changed his lettering of the horizons)

Profile No. 8.

Horizon Ao A grass and moss cover with dead leaves and stems. 3 cm.

" A_1 Peaty, dark brown, loose, humus horizon. 4 cm.

" A_2 Ash colored, loose humus horizon. 13 cm.

" B Humic ferruginous layer, dark brown, somewhat cemented and compact. 15 cm.

" B_2 Light brownish gray, faintly cemented iron and humic hardpan horizon. 15 cm.

" G Soft, sticky, loamy sand.

Profile No. 10.

Horizon A Humic, peaty, black, structureless horizon. 20 cm.

" B Grayish brown, with humus and hardpand. 10 cm.

" G Bluish white, sticky soft slimy horizon with rusty colored horizontal but not abundant veins, compact.

These illustrations give us the regular sequence of the Podsol profile, brought about through the change of relief, or, expressed in another way through the change in the amount of moisture which is used by the processes of soil formation.

The sticky soft slimy material in horizon C of the last two profiles is the material described by the popular name "Glei" in Russia. Wyssotzki[1] adopted it, thus introducing it into scientific literature, and used it to designate those horizons of the profile which were formed mainly under the influence of ground water and only in part under that of percolating water. We shall learn more of the characteristics of these horizons in discussing the moor soils and will use the term "Glei" without attempting to translate it as in the above profiles. In the Podsol soils of lowland areas Glei horizons occur at shallow depths as for example, in a sandy Podsol from Nowo Alexandria, the profile of which is as follows:

			Soil Horizon
Horizon	A_1	Dark gray horizon, black when moist	13-14 cm.
"	A_2	Gray horizon with small white flecks	2-3 "
"	B	Heavier, browner horizon but not more compact	25-27 "

[1] Wyssotzki, "Pedologie" 1905 No. 4 (Russian).

			Soil horizon
Horizon	A_3	Whitish horizon with brown flecks[1] mainly in the upper part	38-39 cm.
"	G	Faintly green, dense horizon bleached by temporary water logging. The boundary between this and the B horizon is sharp.	10 cm.
"	G	Loose horizon similar in color to the last but carries numerous yellowish red iron oxide streaks.	60 cm.
"	G_2	Stratified sand with occasional imperfectly defined yellowish red iron oxide bands.	
"	G_3	Light reddish yellow horizon in which ground water lies at a depth of	230 cm.

This was the stand of the water table Feb. 21, 1910. Feb. 25 it stood at 255 cm. and May 17 at 265 cm. When we remember that the early spring of 1910 was very dry we may assume that in years of normal rainfall the water table will stand higher. In May 1911 it stood 235 cm. from the surface. The average position is indicated by the layer of iron hydroxide. This layer is formed where the surface of the ground water, which carries iron in solution, comes in contact with the oxygen in the soil air.

The greater part of the profiles so far described belong to the Podsolic soils which are characterized by hardpan formation. The faintly Podsolized turf soils should be excepted. As we have seen the Podsolic soils vary considerably according to whether they belong to the sandy or clayey soil group. In those of the sandy group the hardpan forms a continuous unbroken layer which often sends out isolated stringers and branches. In the clayey group, the hardpan is discontinuous taking the form of roundish concretions with an average diameter of 1 to 2 millimeters, often however ranging to a centimeter or more.

P. E. Müller[2] groups the hardpans of the sandy and loamy Podsol soils into three main groups as follows:

A. Hardpan originating through translocation.

1. Clay hardpan. A more or less porous and hard gray sand and clay mixture, unaffected by a treatment of the soil with bases and acids.

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[1] Horizon A_3 is the second Podsolized layer seen in the southern part of the Podsol zone.

[2] P. E. Müller, l c. p. 222 to 223.

2. Peat-like hardpan. Compact, earthy or hard blackish brown, black or bluish black mass with white sand grains throughout. Decomposed by alkaline solutions and by exposure to the air.

B. Hardpan formed by absorption.

3. Humus hardpan. Compact earthy or hard yellowish brown or blackish brown color. It can be destroyed by alkalies. The action of dilute acids is slight. Is decomposed on exposure to the air. Two varieties exist.

A. Humus iron bearing hardpan. It contains more iron than the horizon below it.

B. Iron free or nearly iron free humus hardpan. It is lower in iron content than the horizon beneath it.

C. Concretionary hardpan.

4. Iron bearing sandstone.

5. Impure iron oxide crusts and concretions.

In my opinion the third group need not be separated from the others because: first, the iron-bearing sandstone is not essentially different from the hardpan of the preceding group, and also because Rasen ore is formed in a different way from hardpan. Rasen ore is not the product of secretions from downward percolating waters, as is implied by Van Bemelen[1], but is formed at ground-water level.

We shall not at present concern ourselves with the question whether hardpan is formed by absorption but will defer this until we take up the general discussion of Podsol soil formation.

Ramann[2] identifies three kinds of hardpan as follows:

1. "Brand earth", a layer of easily broken material rich in organic matter lying a short distance below the surface.

2. Stone-like hardpan, brown to black in color which shows a medium percentage of organic material. Found mainly in northern Germany.

3. Brownish to brown, very hard, hardpan containing a great many organic substances. Usually very thick and overlaid by a softer and darker hardpan layer.

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1 Van Bemelen, Zeitschrift für anorg. Chemie, 22, 313, 1900.

2 Ramann, Der Ortstein und ähnliche Sekundärbildungen in den Diluvial und Alluvial sand. Jahrbuch der Kgl. Preusz. geolog. Landesanstalt für 1885, Berlin 1886.

The formation of such hardpan is not found under all Podsol soils by any means. Not only are those soils which we describe as Podsolic or faintly Podsolic (Rasenböden) free from hardpan but in the true Podsols also, the soils in which the A_2 horizon is fully developed, hardpan is often entirely lacking[2]. It follows therefore that for the formation of any of the varieties of hardpans in Podsolic soils other conditions must exist than those which are necessary for the formation of other features of these soils. We shall return later to a consideration of these conditions and at present take up for discussion the chemical characteristics of Podsol soils, beginning with the varieties in which the hardpan is lacking.

I. Podsol derived from Granite

From the basin of the Tungir river in the Joblonowoi Mts.

A. Humus, peaty horizon.

A_2 Whitish horizon, continuous.

B Brownish yellow, fine grained horizon.

C Granite.

The "B" horizon is to be considered in part as an alluvial horizon and not merely as a layer of thoroughly decomposed granite without large quartz grains. Quartz grains do not break up so readily as do those composed of the cleavable feldspars. For the purpose of chemical analysis the materials of horizons A_1, A_2 and B were run through the same sieve so that the maximum size of grain is the same for each.

	A_1	A_2	B	C
H_2O at 100°C	3.06 %	1.69 %	4.10 %	0.98 %
Humus	10.94 "	1.25 "	2.29 "	-
Loss on ignition	12.78 "	5.02 "	6.00 "	1.21 "
SiO_2	66.86 "	74.01 "	63.60 "	74.87 "
Al_2O_3	13.38 "	13.78 "	17.10 "	13.82 "
Fe_2O_3	1.71 "	1.95 "	4.50 "	1.92 "
Mn_3O_4	0.04 "	0.04 "	0.08 "	0.04 "

2 Tumin, l. c. See also Tumin, Journal fur exp. Landwirtsch. 1911, I.

	A_1	A_2	B	C
CaO	1.38 %	0.92 %	0.69 %	0.63 %
MgO	0.14 "	0.13 "	0.45 "	0.40 "
K_2O	2.36 "	2.28 "	4.12 "	3.96 "
Na_2O	1.56 "	1.75 "	3.46 "	2.62 "

If we calculate these analyses on the basis of the content of mineral matter alone we get:

SiO_2	76.42 %	78.01 %	67.65 %	76.17 %
Al_2O_3	15.29 "	14.52 "	18.19 "	14.06 "
Fe_2O_3	1.98 "	2.05 "	4.78 "	1.95 "
Mn_3O_4	0.04 "	0.04 "	0.08 "	0.04 "
CaO	1.57 "	0.97 "	0.73 "	0.64 "
MgO	0.16 "	0.13 "	0.47 "	0.40 "
K_2O	2.69 "	2.40 "	4.38 "	4.03 "
Na_2O	1.78 "	1.84 "	3.68 "	2.66 "

From these figures we see that the horizons A and A_2, especially the latter, contain a higher percentage of silica than the granite, notwithstanding the fact that the large quartz grains were separated out by the sieve while none of the quartz was removed from the granite. A part of the bases[1] also as well as part of the sesquioxides have been removed from the surface horizons. A comparison of the analytical data for A_1 and A_2 with those for 3 will show these facts clearly.

Since we selected, in the above case, a rock rich in quartz, in which a difference in composition between the parent granite rock and the fine earth of the soil is shown to exist it is necessary to compare these results with those of a quartz free rock in order to see fully what changes take place under the operation of the Podsol-forming processes.

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[1] If much humus or peaty material is present the lime content of the surface horizons is much higher.

II. Podsol derived from a dioritic rock

Basin of the Tungir[1] river, Joblonowoi Mountains

A_1 Humus, peaty horizon.

A_2 Whitish horizon, continuous.

B Brownish, fine grained horizon.

C Dioritic rock.

	A_1	A_2	B	C
H_2O at 100° C	7.55 %	2.58 %	3.48 %	0.89 %
Humus	-	2.80 "	1.65 "	-
Loss on ignition	29.45 %	4.19 %	4.74 %	3.37 %
SiO_2	-	69.55 "	62.22 "	54.74 "
Al_2O_3	-	14.96 "	17.93 "	21.28 "
Fe_2O_3	-	3.08 "	4.58 "	2.46 "
FeO	-	-	1.85 "	6.38 "
Mn_3O_4	-	trace	0.31 "	0.43 "
CaO	-	1.62 "	2.08 "	5.65 "
K_2O	-	2.15 "	2.04 "	0.74 "
Na_2O	-	2.57 "	2.81 "	2.75 "
P_2O_5	-	0.07 "	0.08 "	0.31 "

By recalculation on the basis of mineral content alone we receive:

	A_1	A_2	B	C
SiO_2	-	73.28 %	65.38 %	56.78 %
Al_2O_3	-	15.76 "	18.84 "	22.07 "

[1] These two samples were collected by Sukatschoff's Expedition. This was one of the Expeditions sent out by the Emigration Administration for the investigation of soils and vegetation.

	A_1	A_2	B	C
Fe_2O_3	-	3.24 %	4.81 %	2.55 %
FeO	-	-	1.94 "	6.61 "
Mn_3O_4	-	trace "	0.32 "	0.44 "
CaO	-	1.70 "	2.18 "	5.86 "
MgO	-	0.95 "	1.33 "	1.72 "
K_2O	-	2.26 "	2.14 "	0.76 "
Na_2O	-	2.70 "	2.95 "	2.85 "

This example shows that the sesquioxides have been removed from the A_2 horizon to an important extent. This is in general the result obtained from analyses of Podsols free from hardpan.

A_1 and A_2 are eluvial horizons and the translocating processes operating therein operate the same way in both although they differ somewhat in their morphology but, mainly in their color. They are both for this reason designated by the letter A. Horizon B on the other hand is an alluvial horizon, since into this horizon certain constituents are carried from the surface horizons, although in some cases the amount is very small.

In the following table I have assembled a great deal of data concerning those Podsol soils which are characterized by hardpan formations. The analyses of the sandy Podsol from Pomerania is taken from Professor Ramann,[1] the Danish analyses from Tuxen, and the granite Podsols of the Black Forest from Helbig[2].

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[1] Ramann, E. Bodenkunde. Dritte Auflage, Berlin, 191., p. 203.

[2] M. Münst, l. c.

Analyses by Ramann

	Gray or podsolized layer with 1.05% organic matter			Podsol hardpan layer with 7.28% of organic matter			Yellow brown sand beneath the hardpan		
	Soluble in Hcl. %	Insoluble in Hcl. %	Total %	Soluble in Hcl. %	Insoluble in Hcl. %	Total %	Soluble in Hcl. %	Insoluble in Hcl. %	Total %
K_2O	0.0076	0.618	0.626	0.0178	0.754	0.772	0.0085	1.103	1.111
Na_2O	0.0111	0.167	0.178	0.0033	0.360	0.363	0.0213	0.528	0.549
CaO	0.0110	0.060	0.071	0.0194	0.170	0.189	0.0254	0.225	0.250
MgO	0.0026	0.020	0.023	0.0137	0.028	0.042	0.0401	0.064	0.104
Mn_3O_4	0.0032	0.060	0.063	0.0044	0.047	0.051	0.0068	0.026	0.033
Fe_2O_3	0.0964	0.450	0.546	0.1936	0.690	0.784	0.3448	0.760	1.105
Al_2O_3	0.0268	1.650	1.677	1.5256	2.320	3.845	0.4000	3.210	3.610
P_2O_5	0.0059	0.043	.049	0.2966	0.042	0.338	0.0281	0.043	0.071
Total	0.1646	2.068	2.233	2.0744	4.441	6.482	0.895	5.938	6.833

Analyses by Tuxen. (Denmark)

	Percentages of each constituent soluble in Hcl.							
	Peat	Gray podsolized horizon	Hardpan Horizon	Parent material beneath the hardpan	Peat	Gray podsolized horizon	Hardpan Horizon	Parent material beneath hardpan
K_2O	0.055	0.017	0.073	0.084	0.015	0.006	0.008	0.012
Na_2O	0.032	0.005	0.037	0.021	0.006	0.005	0.008	0.004
CaO	0.088	0.007	0.096	0.039	0.038	0.008	0.007	0.006
MgO	0.053	0.005	0.032	0.040	0.009	0.009	0.005	0.002
Fe_2O_3	0.451	0.182	3.720	1.462	0.142	0.053	0.791	0.632
Al_2O_3	0.218	0.265	0.170	1.695	0.382	0.086	0.804	0.191
P_2O_5	0.044	0.011	0.038	0.031	0.025	0.005	0.039	0.008
Total	0.941	0.492	4.166	3.372	0.613	0.172	1.672	0.855
Humus	36.03	2.8	12.02	2.59	13.24	1.76	11.96	1.21

Analyses by Helbig

	Complete fusion analysis			Acid-soluble analysis (Solubility in Hcl.)		
	Gray podsolized horizon	Hardpan horizon	Parent material beneath the hardpan	Gray podsolized horizon	Hardpan horizon	Parent material beneath the hardpan
	Total percent present			Percent of each constituent soluble in Hcl.		
K_2O	3.90	4.48	5.20	0.0935	0.2062	0.2188
Na_2O	3.64	4.63	5.47	0.1223	0.1591	0.0544
CaO	0.17	0.78	0.97	0.1167	0.1819	0.1973
MgO	0.57	0.63	0.69	0.0624	0.3380	0.1421
Fe_2O_3	1.38	4.80	2.33	1.5399	1.5688	
Al_2O_3	10.22	18.56	15.24		12.2624	8.1492
P_2O_5	0.29	0.89	0.58	0.0282	0.1268	0.0920
SO_3				0.0491	0.2552	0.0522
MnO	0.11	4.14	1.12	0.1055	0.5634	0.2363
SiO_2	81.46	62.83	69.61	0.0969	2.2076	0.1178

These analyses are, in a broad way, essentially alike. Horizon A_2, the Podsol horizon, is poorer in bases and sesquioxides than the parent rock while horizon B or the hardpan horizon has a higher content of sesquioxides and of the oxide of manganese. The amount of bases is slightly higher than those in the parent rock at times, though as a rule it is lower. The decomposing action of hydrochloric acid on the hardpan layer is greater than on the parent rock, this being true of the manganese oxide, the sesquioxides, the phosphoric acid, sulphur and silica mainly and less true of the bases. The analyses of Podsols with hardpan published by Münst[1] show the same relationships. The solubility of the alumina especially in the hardpan layer is somewhat higher. Unfortunately no determinations of humus were made. Determination of the loss on ignition gave:

Granite hardpan	(1.	23.38 %
	(2.	21.40 %
Sandy hardpan	(1.	10.82 %
	(2.	3.57 %
	(3	7.03 %

The amount of organic matter in the hardpan is often important therefore.

[1] Münst, l.c. p. 21

In the Glei Podsolic (peaty Podsolic) soils, which constitute transitions to the moor soils the leaching of the A horizon and the accumulation in the B horizon are both less pronounced than in the other Podsols. This is illustrated in the following table[1].

Extract by 10% HCl at 100° C

		Al_2O_3	Fe_2O_3
Loamy Podsol from forest house Ochta, St. Petersburg	A_1 (7-10 cm)	0.288	0.585
	A_2 (11-14 cm)	0.186	0.214
	B (14-18 cm)	7.009	7.290
	B (20-30 cm)	2.815	1.053
	C (85-95 cm)	2.048	1.911
Glei Podsolic soil from forest house Ochta	A (18-29 cm)	0.663	0.117
	A_2 (29-35 cm)	0.926	0.254
	B (40-60 cm)	1.748	0.975
	G (70-80 cm)	0.650	2.114

The concretionary hardpans of the argillaceous Podsols often contain also a noticeable amount of sesquioxides and manganese dioxide as is shown by the following analyses of soil horizons from the province of Smolensk.

Horizons	Depth	Fe_2O_3 plus Al_2O_3	Mn_3O_4
A_1	2-7 cm	31.94 %	18.12
A_2	16-21 "	23.73 "	2.46
B	60-65 "	25.46 "	5.06

The hardpan concretions and horizon A_2 of the argillaceous Podsolic soil of Bikszad, Hungary, have the following composition[2].

	Horizon A_2	Ortstein (hardpan)
Loss on ignition	5.30 %	6.45 %
SiO_2	77.58 "	51.59 "

[1] I. Wityn, Russian Journal for Experimental Agriculture, 1911, 2. See also B Frosterus, Geologiska Kommission i Finland, Geotekniska Meddelanden No. 10, 1912.

[2] K. Glinka Földtani Közlöni, 41, 1911.

Table continued:

	Horizon A_2	Ortstein (hardpan)
Al_2O_3	11.99 %	10.67 %
Fe_2O_3	2.88 "	14.49 "
MnO	-	12.93 "
CaO	0.81 "	1.91 "
MgO	0.61 "	0.93 "
K_2O	0.95 "	1.13 "
Na_2O	0.74 "	1.06 "
Total	100.86 "	101.09 "

In the following table showing the composition of a Podsolic loam from the province of Smolensk[1] the distribution of humus in the Podsolized and hardpan horizons is clearly shown.

Depth in cm.	Soil horizons	The Soil: Humus %	The Soil: Loss on ignition %	Concretions: Humus %	Concretions: Loss on ignition %
2-7	A_1	6.28	10.22	5.28	15.37
16-21	A_2	0.595	1.98	1.57	6.02
27-32	B	0.460	5.34	0.996	6.35
60-65	B	0.258	5.55	0.66	6.47
100-105	B	0.371	5.27	0,65	5.55
130-135	C	0.143	5.46	0.53	5.91

A sharp boundary between horizons A_1 and A_2 is a characteristic of the humus of Podsolic soils as well as the appearance of a second humus layer on a deeper horizon. This fact is not accidental nor limited in its application for it is noticeable in all the analyses of the Podsolic soils of the province of Smolensk.

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[1] Tumin. l. c.

A sudden transition from horizon A_2, to horizon B is found also in the humus content of the hardpan concretions, though less sharp than in the Podsol horizons themselves. As a whole the content of humus in the concretions is greater than in the soil itself with the exception of horizon A_1.

In order to complete the general discussion of the chemical characteristics of the Podsolic soils we must take up rather critically a discussion of the results obtained by leaching the soil with water, which brings out some characteristic properties.[1] The water extract shows an acid reaction, decreasing in acidity with increase in depth. The amount of organic material is greater than that of the inorganic, the amount of the latter decreasing with depth, according to the following analyses of the granite Podsol soils of Jakutsk:

In 100 grams of air dry soil:	Horizon A_1	Horizon A_2	Horizon B
Color of the extract	Yellow	Faint Yellow	Colorless
Acidity expressed in gr. of NaOH	0.0064	0.0033	0.0017
Residue on drying	0.0807	0.0480	0.0254
Inorganic material	0.0139	0.0100	0.0082
Loss on ignition	0.0668	0.0380	0.0172
SiO_2	0.0008	0.0016	0.0010
$Al_2O_3 + Fe_2O_3$	0.0038	0.0018	0.0008
CaO	0.0014	0.0020	0.0015
MgO	0.0001	0.0012	0.0008
K_2O	0.0005	0.0005	0.0014
Na_2O	0.0017	0.0010	0.0006
P_2O_5	0.0002	trace	trace
Cl	0.0052	0.0019	0.0023
SO_3	0.0013	0.0014	0.0010

[1] Sacharoff, Journal of Experimental Agriculture, No. 4, 1906 (Russian)

The acid reaction of the water extract of the Podsolic soils is not dependent on free or (in the form of bicarbonates) half combined carbonic acid. If 50 cc of the extract be evaporated by boiling to 5 cc the concentrated extract still shows an acid reaction[1].

A comprehensive consideration of all the facts of morphology and chemistry so far observed shows that the first striking feature of these soils is that the weathering processes by which they are developed operate in an acid medium. If we compare chemical composition of the eluvial horizons A_1 and A_2 of the Podsol soils with that of the parent rock from which they have been derived we find evidences of the subjection of the former to the action of acids. Not merely the bases of the aluminum silicates of the eluvial horizons but the sesquioxides also have been removed with the bases and the humus and carried to the deeper horizons. This phenomenon cannot be explained as due to simple hydrolysis, neither can the sesquioxides be carried away as a mechanical transport of the iron in the form of finely suspended hydroxide or the alumina as a constituent of the clay. That such mechanical translocation does take place in Podsolic soils, transporting the finest soil particles from the surface horizons to the deeper was assumed by both Müller and Mayer; but such process did not form hardpan like that of the granite soils of the Schwarzwald or the loamy Podsols of the province of Smolensk and the vicinity of Bikszad in Hungary. The alumina of these hardpans is easily soluble while at the same time only a small part of the silica goes into solution so that the presence, in such hardpan, of aluminum oxide in the form of aluminum silicate can hardly be accepted. It is possible that the alumina is combined with the organic matter which favors its splitting off from the aluminum silicates as well as its transportation downward in the form of pseudo-solutions.

The investigation of the humic material in the Podsols shows for horizon A_1 the presence of substances which are known under the names of humic and crenic acids. In horizon A_2 crenic acid is present almost exclusively. If the solution reacts acid the humic acid cannot be extensively removed for it is soluble only in alkaline solutions. The crenic acid on the other hand can be removed to considerable depths by water. On that account almost colorless water extracts of the Podsolic soils have a high content of organic substances. The same acid as well as its compounds determines the white color of these soils as is shown by the following test:- If we ignite or heat to redness a sample of the A_2 horizon of Podsolic soils, it becomes at first darker, dark gray, but later changes to a yellowish brown or brownish color through the gradual loss of organic compounds.

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[1] It is a noticeable fact that the Glei horizons of the Podsol soils described on a preceding page react alkaline. We shall return to this phenomenon in the discussion of Moor soils.

Crenic acid is present not only in Podsols but also in many other soils. Since they are unsaturated or only partly neutralized by bases in Podsols alone, they can react acid only in such soils. The cause lies in the loss of the bases from the organic material out of which humus is formed before it has been converted into humus. On being carried into the lower horizons of the soil the crenic acid becomes saturated with bases so that the Podsolic soils lose their acid character with depth. This phenomenon explains why those horizons of the Podsolic soils to which a pure white color is characteristic are not always the most thoroughly leached horizons. It has often been noticed that when a portion of the white or gray horizon of a Podsol soil is ignited it assumes a more intensive iron color than is received on the ignition of a portion of a darker colored layer. In the first case the white color is due to the more thoroughly saturated, but more feebly acting crenic acid while in the second we have to do with a less saturated and for that reason more strongly acting acid.

That Podsol soils can be separated into two sub-groups has already been mentioned. In the one the hardpan formation appears in the form of concretions, unbroken bands or well developed layers, while in the other it is absent entirely or present only as an alluvial horizon which as compared with the eluvial horizon is richer in soil particles of the smallest size and in sesquioxides.

Field observations[1] show that hardpan is developed in those soils which occur in the lower lying localities and for this reason become correspondingly saturated with water so that reduction processes may take place in them.

Hesselmann[2] found that in the surface horizons the sour soil rich in organic matter intercepted the oxygen present in the atmospheric waters so that oxygen free water only reached the deeper lying horizons. If the atmospheric water is present for some time in such abundance as to prevent the penetration of atmospheric oxygen into the lower soil layers conditions are thereby produced which favor the reduction processes. Iron and manganese compounds are dissolved and carried into the deeper soil horizons. As soon as the surface layers are freed from excess moisture and become penetrable to the atmospheric oxygen oxidation processes begin to operate. The ferrous compounds change to ferric compounds, become insoluble and are precipitated forming the hardpan layer[3].

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1 Tumin, l.c.

2 H. Hesselman. Om vattnets syrehalt och dess inwerkan på skogsmarkens försumpning och skogens vaxtlighet. Meddelanden fran Statens försöksanstalt, H. 7, 1910.

3 A. Mayer, Landw. Versuchst., 1903, 58 S. 161, Tumin entertained the same opinion.

These alternating reduction and oxidation processes affect not merely the iron and manganese compounds but the humus material as well, so that the latter occur in greater or less abundance in the hardpan. In soils low in their content of iron, humus substances are predominant in the hardpan; in those rich in iron on the other hand they are subordinate in amount. On this basis hardpans are designated as strongly organic and faintly organic. While the carbon content of the hardpan humus obtained by alkali extraction has been calculated at 55 to 47.5 per cent, A. Mayer[1] shows that the humus substances of Podsol soils obtained by alkali extractions have a carbon content of 59 to 60 per cent. A part of the hardpan humus substances are soluble in hydrochloric acid and correspond in composition and characteristics to the so-called Apocrenic acids. These acids are supposed to originate through the oxidation of crenic acid which as we have already seen is characteristic of Podsol soils.

The morphological differences between the hardpans of the loamy soils and those of the sandy soils are due to the mechanical composition of the soils. When the penetration of water and air into the rock mass takes place more or less uniformly, in sandy soils for example, a continuous, unbroken layer or hardpan is formed. In rocks or unconsolidated material of less penetrability to water and air, such as loamy or sandy loam soils, large irregular hardpan concretions originate, and in rocks that are least penetrable to air and water, such as silt and clay materials, more or less round concretions are developed. In heavy soils the percolating water changes rapidly from a capillary status to that of adsorption[2] to the surface of the soil grains. The solution layer or skin surrounding each soil grain or group of soil grains, being under considerable permanent pressure[3] is favorable to increased concentration of the materials dissolved in it and to its more rapid secretion or crystallization. In this way many round concretions are formed in nature.

We come now to the consideration of those Podsolic soils which occur in regions having at an earlier period a dryer climate than at present. The soils of this group are to be considered as degradation products. At first attention will be directed to the forest loam or gray forest soil. Rupprecht[4] mentions in his well known work that Plagge, the head gardener at the University of Kazan first recognized their character. Although Rupprecht, Plagge and other investigators knew that these gray soils rather than true Tschernosems are found in the Russian Tschernosem region within local forested areas, they did not interest themselves in their

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1 A. Mayer, Landw. Versuchst., 1904, 60, s. 475.

2 Rene d'Andrimont, Verhandlung der zweiten internationalen Agrogeolgen Konferenz, Stockholm, 1911. und andere Werke von ihm.

3 See also S. Lagergren, Fortschritt der Physik 55, I, S. 648.

4 Rupprecht, Geobotanishche Erforschungen des Tschernosems. Beilage zum X.Bd. der Verhandlung d. Kaiserliche Akademie der Wissenschaft, No. 6, 1866.

characteristic morphology. In 1883 Dokutschajeff[1] attacked this question for the first time and the matter was thoroughly worked out by the members of the Nishni-Nowgorod and Poltawa soil expeditions. In 1888 Dokutschajeff[2] attacked the question again with special reference to the formation and structure of these soils, and their origin was fully discussed at the same time by Kostytscheff[3] and Korshinsky[4].

In his first works Dokutschajeff considered the forest soils as independent soil types with characteristics of their own developed in the Steppe region independent of the Tschernosems and under the influence of special conditions. Korshinski, who traced out the northern boundary of the Tschernosem in the eastern part of Russia, considered the forest loam as the result of gradual change of the Tschernosem under the influence of the advancing forest. Such changes were designated as degradational.

The forestation of the Steppes effect a change in the conditions under which soil development goes on. The covering of forest trees changes the moisture of the air, that of the surface soil and the subsoil and substratum. If we content ourselves with the consideration of the temperature and moisture of the air and of the soil in the forest itself and in its vicinity, we shall obtain results which will make the appearance of the degradation processes seem a matter of course. It will not be necessary however to enter at all into the discussion of the still unsettled question[5] as to whether the forested or prairie regions receive the greater atmospheric precipitation.

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[1] Dokutschajeff, The Russian Tschernosem, 1883 (Russian).

[2] Dokutschajeff, Die Methoden der Lösung der Frage von der Waldexistence in der Südsteppe von Ruszland, 1888.

[3] Kostytscheff. Die Arbeit der Naturforsch. Gesellschaft zu St. Petersburg, 20, und die Forst und Landwirtschaft in Ruszland, 1903.

[4] Korshinski, Arb. der Naturforschend. Gesellsch. zu Kazan, 1887, 17, No. 6, und 18, Lief 5, 1888.

[5] In the following works the reader will find sufficient material for answering this question:
Adamoff, Die Arbeiten und Versuche des Forstwesens, Lief 1, 1902 (Russian)-- Auderlind, Meteor. Zeitschrift, 1886, 3, S. 47.-- V. Bebber, Centralbl. für das gesammte Forstwesen, 1878, S. 261.-- Bequerel, Comptes rendus, T. LVII, 1867 - Breitenlohner, Centralbl. für das Gesamte Forstwesen, 1877, S. 325, 1878, S. 16 und 407.-- Bühler, Ebermayer, Hoppe, Muttrich, Meteorol. Zeitschrift, 1899, H. 10, S. 469 to 472 - Dimo, Pedologie, 1904, No. 1. (Russian) -- Ebermayer, Die physikalische einwirkung des Waldes auf Luft und Boden, Aschoffenburg, 1873; Wollnys Forschungen, 12, 1899, S. 147-174; Physiol. Chemie der Pflanzen, 1882; Meterolog. Zeitschrift, 1896, 12, S. 169. -- Ein flusz der Wälder auf Luft und Boden, u.s.w., 1900. -- Faukhauser, Wollnys Forschungen 5, 1882, S. 316. -- Fautrat, Comptes rendus I, 2, 30, 1875 p. 206, 1454, 5, 83, 1877; 85, p. 340, 1115 --

Observations at a great number of forest experiment stations in Germany, Austria, France and Switzerland show that in forests the air and soil temperature are low, although in annual mean they do not reach so low a level as in regions without forests.

Although a forest cover, exhausts the moisture from the deep subsoil and lowers the level of the water-table, yet the surface horizons of the soil and the soil surface are more moist under a forest cover, because of low insolation and low evaporation, than in areas not covered with forest.

Uniform temperature and abundant moisture favor the energetic decomposition of the organic material and decomposition products are formed which differ from the corresponding products formed in the steppes.

Footnote #5 continued

Fautrat, C. R., T. LXXX, 1875, p. 206, 1454, T LXXXIII, 1877; T LXXXV, p. 340, 1115 - Fautrat et Sartiaux, T. LXXIX, 1874, pp. 409-411 - Ferrel, The Amer. Meteor. Journal, 1889, Vol V. p. 453 - Hamberg, Om Skogarnes inflytande på Sveriges Klimat, Stockholm 1885; - Hann, Meteorol. Zeitschrift, 1886, 3,S. 412. - Henry, Pedologie, (Russian), 1903 No. 1. - Hoehnel, Wollnys Forschungen, 2, H. 4, 1879, S. 398. - Hornberger, Forstl. Blätter, 1888, 12, S. 225. - Kudritzsky, Verhandhungen der Kiewschen, Naturf. Gesellsch., 11, 1890 (Russian) - Krawtschinski, Forst - Journ. 1876 (Russian) - Lendenfeld, Petermanns Mitteilungen, 1888, H. 3. - Lendenfeld, Meteorol. Zeitschr., 1890, 7, H. 10, S. 361; Mitteilungen V. Forstl. Versuchswesen in Oestreich, 13, S. 1 - 447 - Matthieu, Meteorologie comparei agricole at forestiere, Paris, 1878 - Morosoff, Pedologie, 1899 Nr. 3. 1900, Nr. 2. 1901, (Russian); Die Arbeiten des Forstversuchswesens, 1900, 1902 (Russian); Wald und Boden, Devriens Lexikon, 5 (Russian); Zeitschrift für Forstbetrieb, 1905, Nr. 40 (Russian) - Müttrich, Die Ergebnisse der Beobacht. der forst. Meteorol. Station Preuszen usw, 3 Jahrgang, 1877; Beobachtungen der Erdtemperatur auf der forst. meteorol. Station in Preuszen, Braunschweig, und Elsass-Lothringen, Berlin 1880; Zeitschrift für Forst und Jagdwesen, 1890; Meteorol. Zeitschrift, 1900, H. 8, S. 356 - Ney, Forstwesenschaftl. Centralblatt, 1901. - Nördlinger, Naturforsch., 1886, 19. - Ototski, Die Grundgewässer, ihre Entstehung und Verteilung, II Die Arbeiten des Forstwesens, [illegible] 1905. - Riegler, Mitteil. aus d. forst Versuchswesen Oesterreichs, 2, H. 2, 1879. - Pearson, Rolph, The Indian Forester, 1907, Febr. p. 57 - Schubert, Der Jahrliche Gang der Luft - und Bodentemperatur in Freien und in den Waldungen und der Wärmeaustausch im Erdboden, [illegible] Berlin 1900 - Tolski, Pedologie, 1902. - Woeikoff, Das Klima der Erdkugel, 1884. - Wollny, Forschungen, 10, 1887, 13, 1890, 17, 1894; Vierteljahrsschrift des bayerisch. Landwirtschaftsrates, 1900, H. 3. - G. Wyssotzki, Pedologie, 1899 Nr. 3, 1901, 1902, 1904; Arbeiten der Mitglieder des III Kongresses des Forstversuchswesens, 1895; Gegenseitige Beeinflussung der Waldvegetation und der Feuchtegkeit, T. I, 1904; Die Arbeiten des Forstversuchswesens, 1901 - Zschacks, Wollnys Forschungen, 1891, S. 462.

Since humus formation is seemingly due, in the main, not to bacteria, but to fungi which find more favorable conditions for existence under the forest cover with its more abundant shade and the more uniform moisture condition of both the surface soil and the surface cover than in the steppes, the rapid decomposition of the organic forest remains is evident[1]. The equilibrium between the accumulation and decomposition of organic matter that existed under steppe conditions becomes destroyed under a change to forest conditions. The forest debris as well as the old steppe humus begin to decompose. The roots of the forest vegetation which do not form any dense net work do not supply the abundant organic material supplied by the dense growth of grass roots. The larger roots of the forest trees decompose often in the interior leaving a thin outer hull of material. The gradual change from dark to light color of the forest covered Tschernosem takes place first in the deeper horizons, that of the surface taking place later. This phenomenon is doubtless connected with the distribution of the tree roots in the soil along the courses of which the moisture reaches the distant branchings of the root system more rapidly than by percolating through the soil mass.

The soil solution beneath the forest reacts acid, containing crenic acid. The soil type in this case is really identical with the Podsolic soils for while century long accumulations of humus are being destroyed the Podsolization of the humus soil horizon is taking place. The deeper lying horizons down to a certain depth are leached of their lime carbonate (and of their gypsum also if originally present) and at the same time they are given, as we shall see later, a character of their own.

In addition to these studies in the field, experimental investigations have been made by Kostytscheff which bring out the processes that operate in nature, even though the experiments seem more or less artificial. He[2] placed 300 grams of Tschernosem from the province of Ekaterinoslav in each of two vessels in such a way that it formed a 6 inch surface layer in each. One of the vessels was covered with a layer of 150 grams of oak leaves. This soil was maintained in a super saturated condition so that a part of the water percolated through and into a vessel below. The amount of water used in this experiment was about as follows:

For the Tschernosem with leaf cover 10100 ccm.
" " " without leaf cover 10125 ccm.

1 In semi-arid regions the accumulation of humus under forest cover is greater than in treeless areas.

2 Kostytscheff. Die Arbeiten der St. Petersburger Naturforscher-Gesellschaft, 20,

The water filtering through to the vessel below was colorless, but in a short time a white substance began to form as a precipitate which proved to be lime carbonate. The experiment continued a year. The water that percolated through the soil was collected, evaporated in platinum dishes and the residue analyzed with the following results.

	In the dry soil	In the percolates	
		Soil with leaves	Soil without leaves
	%	%	%
Humus	8.461	-	-
Chem. comb. water	3.258	-	-
Loss on ignition	11.718	1.9012	1.2530
SiO_2 in soda solution	16.508	0.3128	0.1705
Al_2O_3)	6.337)	)0.2704	)0.0204
Fe_2O_3)	4.984)	)	)
Mn_2O_3	0.234	0.1018	0.0219
CaO	2.088	1.3569	1.7618
MgO	1.715	1.3483	0.3667
K_2O	0.736	0.0726	0.0496
Na_2O	0.103	0.0654	0.0593
P_2O_5	0.168	0.0053	tr.
SO_3	tr.	0.0839	0.1611
CO_2	0.424	-	-

Total dissolved matter 24.938

Total undissolved " 63.344

The determination of the humus in the vessels after the experiment gave the following:

In the soil with leaf cover 7.30%

In the soil without leaf cover 6.57%

Since each sample contained 253.83 grams organic matter before the experiment, the amount decomposed in its course was as follows:

In the soil with leaf cover 34.8 gr.

In the soil without leaf cover 56.7 gr.

Consequently the cover of leaves decreases to an important extent the loss of humus, a matter about which there can be no surprise since they contain humus material themselves. After the experiment the color of the Tschernosem had become similar to that of the forest soil. From the soil with the cover of leaves about 6 grams of dry matter was received, while from the one without the leaf cover 4 grams were received, corresponding to .2% and .13% respectively. At the same time the plasticity of the soil was decreased. After a three year investigation only 2.5% of humus had been left in the soil.

The capacity of the Tschernosem to degrade is thus shown. The increase in the amount of moisture used by the soil processes must be regarded as the principal cause for the degradation. From this we conclude that the importance of the forest in the degradation processes is increased in proportion to the increase in the amount of moisture in the upper horizons of the soil. There are possible cases also in which the degradation takes place under the influence of an increase of moisture without the accompanying influence of forests.

The morphology of the soil profile of the gray forest soil was described in the investigation of the soils of the Province of Poltawa, as follows[1]:

A_0 Forest Trash, 2.5 to 5 cm. thick, composed of slightly decomposed dark brown leaf mold, small twigs, acorns, and other remnants of forest vegetation. Occasionally small lumps of structureless organic matter are present.

A_1, Dark brown, brownish gray to light gray layer, fine grained to very fine grained with pea structure. In depth the color becomes lighter and the pea-like grains larger. At 24 to 36 cm. in depth they reach a walnut size.

A_2, The Ashy gray, so-called nut-like horizon. In dry condition it falls, when shaken into small angular lumps, or "little nuts", each covered with a thin layer of ash-like powder. Their diameter increases and the soil becomes more compact with depth. The thickness of horizon A_2 amounts to 47 or 48 cm.

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1 Gieorgiewski. Wertschätungsangaben der Böden des poltawaschen Kreises des Gouvernements Poltawa, I, 1890, St. Petersburg.

B_1, Reddish brown compact loam, which has become colored with humus and has a nut structure in the upper part. In the cracks and pores dark brown coatings are noticeable which are characteristic of soils influenced by forest[1]. In Poltawa the thickness of the horizon is about .7 to 1.4 meters.

B_2, Brownish, strongly calcareous loam which in places passes into hard white marl 0.7 to 1.4 meters thick.

C, Yellow loess.

The above is the typical arrangement and character of horizons in typical gray forest soil[2].

The end product of the changes producing gray forest soil is soil with Podsolic characteristics. Between these and true Tschernosem all intermediate stages are found. The latter are termed degraded Tschernosem if in their general features the typical characteristics of forest soils are only faintly developed, and those of the Tschernosems are predominant. Horizon A_1 is darker and in certain varieties is nearly black in the field. Horizon A_2 is also darker and has a faintly developed nut structure. B_1 and B_2 are either more faintly developed or are merely in the first stages of change.

There is still another variety of broken down Tschernosem not due to the influence of forest growth but to a change of climate from dry to wet. Such soils have been identified along the northern part of the European Tschernosem belt especially near its western end. It has often been my good fortune to study such soils in the Groubeschow district of the Lublin province in Russia. Horizon A_1 is light colored, often strongly Podsolized and leached, while A_2 is darker. Reddish brown horizons do not exist. Effervescence in acid takes place immediately below horizon A_2 while in the degraded Tschernosem of the first kind the carbonate horizon often lies deeper.

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1 Bogoslowski, "Pedologie", 1903, No. 4 (Russian).

2 Soils with identical profiles are known to occur in the northern Podsol zone of Russia, in Pskow. They overlie typical compact sticky morainic clay containing no bowlders in its upper horizons. Such regions are covered with oak forests with occasional hazel and ash. Only in their humus horizons are they like forest soils of the steppes and steppe borders. The deeper lying horizons, B_1, B_2 and C of the forest soil and of the Podsol are entirely different.

The well known degraded Tschernosem found in many parts of European and Asiatic Russia was found by Bogoslowski[1] also in western Europe. A soil profile from the southern border of the North German lowland at Hildesheim was described as follows:

1. Dark brown horizon, porous and lumpy, on drying it breaks up in places into lumps like soils with faint nut structures. Does not effervesce in acid. Thickness .50 m. Horizons A_1 and A_2 are contained in this layer.

2. Brownish yellow loam with small bowlders, traversed by numerous root passages. On the walls of cracks and cavities characteristic coatings were noticed. In the deeper lying horizons whitish carbonate rods, spots and concretions were present in places. In places the concretions remain intact and show that before the appearance of the forest vegetation a steppe vegetation was present and exerting its influence actively. Occasionally also holes made by burrowing animals[2] were found filled with a brownish mass on which one could see the evidences of the later degradation which took place under the influence of the acid forest humus. The thickness of the whole horizon B and a part of C was included within the depth lying between .5 and 1 meter. Below this lay black clay of the lower cretaceous.

The transition stages between forest soil and Podsol soil became known in part through the investigations of the province of Nishnij Nowgorod[3]. From southeast Russia such soils were described by Rispoloshenski and by Freiberg[4] from the province of Orel. In both, the A_1 horizon is of gray or brownish gray color, structureless and either dusty or muddy according to the weather. The thickness of the horizon is about 16 centimeters on the average, ranging from 9 to 29. Horizon A_2 is mainly grayish blue usually with a white shade and always breaks up into characteristic small plates and fragments covered with a whitish fine grained powder. The average thickness is 14 centimeters, though the range is considerable. Horizon A_2' is brownish gray, and the particles are covered with dark dirty often whitish specks. It breaks up likewise either into small plates and "nuts" or often into small "nuts" only. The whitish fine grained particles are not so numerous here however as in the above described horizons.

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1 N. Bogoslowski, Ibidem.
See also Rispoloshenski. Report to the Agricultural Department of the Minister of Agriculture on the Investigations of Soils 1893-1895 Tkatschenko, Verhandl. des Kaiserl. Forstinstitut XVIII, 1908.

2 These features will be fully discussed along with the description of Tschernosem soils.

3 Angaben zur Wertschätzung der boden des Gövernments Nishnij Nowgorod, I-XIV.

4 Freiberg. Wertschätzungsangaben der Böden des Gouvernements Orel Kreis Kromy, 1902. Kreis Dmitrow 1903.

From the more or less unbroken horizon A_2' occasional whitish and dirty brown flecks pass over into horizon B. The mean thickness of A_2' is about 19 centimeters, ranging from 9 to 29. Like the typical forest soils horizon B has here a bright red color. Loess, horizon C, lies at 1 to 1.5 meters beneath the surface where effervescence in acid takes place.

In the Podsolic soils of ancient Steppes or steppe borders the development of a reddish brown B horizon takes place. Such soils form the most characteristic part of the so-called Brown Earth of Western Europe. We shall take up this soil for discussion further on.

From the chemical point of view, the following analyses show the characteristics of the forest soils of the Poltawa[1] district:-

	Loss on ignition %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	CaO %	MgO %	$CaCO_3$ %	$MgCO_3$ %
Horizon A	8.41	73.6	10.36	3.01	1.39	undet.	-	-
" A_2 (nut struct)	7.56	71.54	11.05	3.7	1.54	0.64	-	-
" B_1 (red brown)	8.42	70.11	11.84	3.54	1.07	0.95	-	-
" B_2 (marly)	-	-	-	-	-	-	1.36	23.94
" C (unchanged loess)	6.35	75.84	10.35	1.92	1.83	0.54	0.03	2.7

Bogoslowski[2] obtained similar results for the reddish brown horizon of the forest soils of the province of Tula.

Reddish brown horizon B	Loss on igni- %	Water at 105° C: %	Humus %	CO_2	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O + Na_2O
1 to 2 meters below the surface is	7.83	3.79	0.49	0.0	69.49	12.60	5.25	2.63	0.48	2.38
the unchanged loess	7.81	1.68	0.29	3.46	70.51	11.38	2.50	4.14	1.60	5.50

1 Gieorgiewski, Valuation estimates of the soils of Poltowa, I, 1890, p. 122 (Russian).

2 Bogoslowski, Bulletin du Comité geologique St. Petersburg, 23, S. 337-343.

The acid extract (HCl) of the forest soil from the province of Kursk obtained in the laboratory of Kossowitsch[1] had the following composition:-

	Humus	N	P_2O_5	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O
Horizon A_1 (10 to 15 cm.)	3.02	0.13	0.07	0.92	0.98	0.29	0.22	0.14	0.07
Horizon A_2 (30 to 45)	0.51	0.03	0.07	1.14	0.92	0.18	0.21	0.11	0.04
Horizon B (60 to 97 cm.)	0.34	0.03	0.10	3.47	2.46	0.33	0.49	0.36	0.11

In these latter analyses horizon C is not given. The character of horizon B comes out strikingly being highest of all in the percentage of sesquioxides and lowest in silica.

The humus content of the forest soils depends on that of Tschernosem in the region from which the sample was taken and the intensity of the degradation processes. Horizon A of the forest soil of the province of Poltawa where the humus content of the Tschernosem is not high as an average contains 2 to 4 per cent of humus. The humus content[2] of samples taken from the forest is always higher than that of samples taken from cultivated areas. This phenomenon can be observed in Podsol soils, also, and in still other types cultivation is apparently the cause of a decrease in the humus content[3].

In the forest soils of the province of Orel, where the Tschernosem contains 6 to 10 per cent of humus, there is a content of humus ranging from 2.5 to 6 per cent, the latter being the maximum percentage occurring in degraded Tschernosem while the former approaches the percentage characteristic of Podsol soils.

The solubility in water of the humus of forest soils is not inconsiderable. For example the analyses of Lesniewski[4] show that 2 per cent of the total soil humus in horizon A_1 and 5 per cent in

1 Tkatschenko. On the Importance of Forests in Soil Development. Proceedings of the Imperial Institute of Forestry, 18, 1908 (Russian).
2 Glinka, K., Data on the Value Estimation of the soils of Poltawa, 4, 1891, p. 62, (Russian).
3 Pankow, Journ. der experim. Agronomie, 11, Lief 2.
4 Lesniswski, Mitteilungen des Institutes zu Nowo-Alexandria, 10, Lief 2.

A_2 went into solution. For typical podsolic soils the solubility of the humus amounts to an average of about 3 percent for the A_1 horizon and to 5 to 10 percent for the A_2 horizon. This is somewhat greater in both horizons than in the forest soils.

In the forest soils the amount of humus decreases with depth less rapidly than in the typical podsolic soils. According to the results published by Bogoslowski[1] the vertical distribution of the humus is as follows:

		Percent of decrease
Surface horizon	2.18 %	
		11.4
At a depth of 16-19 cm.	1.93 "	
		22.2
At a depth of 26-27 cm.	1.50 "	

According to the reports of Sacharof[2] on the water extracts, Horizon A_1 reacts faintly acid. The strength of the reaction decreases with depth however as in the podsolic soils, becoming first neutral and finally alkaline. In horizon A the amount of dissolved organic substances is greater than that of the inorganic substances but in the deeper horizons the solubility of the inorganic substances is greater than that of the organic.

These conclusions drawn by Sacharof[3] were based on the following analyses of samples of forest soil from the village of Aleschni in Riasan and from the village Dikanjka in Poltawa. The former is a light gray, the latter a dark gray variety.

Investigations of water extract from gray forest soil.

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1 Bogoslowski, Material der Untersuch der russ Böden, Lieferung VI, 1890.

2 Sacharof, Bodenlösungen. Journ. der experimen. Agronomie, 4 1906.

3 Sacharof, Bodenlösungen, Journ. der experim. Agronomie, 4, 1906.

	Depth at which the samples were taken in cm.	Color of the Extract	Residue on Drying	Residue on Ignition	Loss on Ignition	Acidity as NaHO	Alkalinity as $2(HCO_3)$	Cl	SO_3	SiO_2	CaO
		Amount contained in 100 parts of the dry soil.									
I	10 to 15	Brownish	0.0947	0.0245	0.0402	0.0036	-	0.0046	0.0037	0.0024	-
	58 to 63	Colorless	0.0340	0.0132	0.0209	Neutral	-	0.0045	0.0014	0.0040	0.0074
II	0 to 22	Brownish	0.0901	0.0227	0.0674	0.0010	-	0.0023	0.0028	0.0055	0.0086
	133 to 152	Colorless	0.0522	0.0329	0.0193	-	0.0495	0.0058	0.0053	0.0038	0.0174

We have already mentioned that in typical Podsolic soils which ave developed in regions that have had periods of dry climate in he past, horizon B has a reddish brown color. The Braunerde of amann[1] belongs to this group in my opinion.

In the vicinity of the village of Solymar, near Buda-Pesth, I ad the opportunity of studying this soil, overlying loess in this ocality. I convinced myself here that the so-called Braunerde must e placed in the Podsol group of soils. Where it is covered with orest the Podsolized humus horizon, under which the compact brown orizon lies, can be easily seen[2]. Where the soil has been cultivated the faintly developed A_1 and A_2 horizons are mixed with orizon B and the reddish brown color appears at the surface. Traces f the Podsolizing processes are shown in shallow depressions. The oils are like the Podsols found in the vicinity of Nowo-Alexandrija hich have been developed from loess. The Podsolizing and leaching as reached a more advanced stage of development in the latter than n the former. The following is a description of a soil profile hat was exposed in the upper part of a loess excavation between the illage Wlostowitze and Skowieschin in the Nowo-Alexandrija region:

1. Light gray humus horizon of the Podsol soil (A_1) 30 cm.

2. Whitish gray horizon uniformly Podsolized throughout (A_2) 18 cm.

3. Layer with Podsolized flecks on the reddish brown ground color (A_2').

4. Reddish brown more compact and tough. This horizon differs more from any horizon in any of the profiles previously described than any other member. Often contains soft dark spots and occasional whitish flecks and streaks. (B) 38 cm.

5. Whitish flecks and streaks begin to predominate over the reddish brown and dense mass (A_3) 30 cm.

6. Reddish brown mass occurring only in the form of thin layers. The whole horizon consists of a whitish friable, seemingly stratified mass consisting of the same constituents as the spots and streaks of the above names horizon 36 cm.

7. The apparent stratification disappears. The profile has the same shade of color throughout but dark flecks show plainly in the otherwise uniform ground color, the spots are not however sharply bounded. (B_2) 45 - 47 cm.

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[1] Ramann, E., Bodenkunde, 2 Auflage, 1905, S. 405.

[2] Glinka, K., Ueber die Sogenante Braunerde "Podologie" Nr. 1, 1911.

8. Thin dark faintly developed streaks with humus secretions 3 - 5 cm.

9. Unchanged loess.

Effervescence with hydrochloric acid begins at a depth of 2.14 meters, immediately under horizon 8.

Since the general character of all the other soil profiles of this region are wholly like this one it is not necessary to quote them in detail. The order in which the several horizons occur is always the same so the only variations that occur are in the thickness of the several horizons, due to the changes in local relief, and in the depth at which effervescence occurs. On the hills or knolls the humus horizon is often absent and the reddish brown B horizon appears at the surface.

The following table shows the results of a mechanical analysis of the soils of Nowo-Alexandrija[1]. The samples for analysis were taken from the locality of the profile just described.[2]

Size of particles in m.m.	Number of the Profile Horizons						
	2	3	4	6	7	8	9
More than 0.25	0.75	-	-	-	-	-	-
0.25 to 0.05	27.25	24.50	27.50	28.00	16.25	15.50	20.50
0.05 to 0.01	50.00	55.00	45.25	56.25	62.40	60.75	63.25
Less then 0.01	22.00	25.50	27.25	15.75	21.35	23.75	16.25

From these figures it is seen that although the two lower horizons are finer in grain than the parent rock itself, they all have however, more or less, the same typical appearance. This was evident from an examination on the ground. The mechanical composition of the other horizons is characterized by a marked reduction of the coarse silt to such an extent that it does not dominate the whole mass.

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1 Der Loess wurde zuerst mit schwacher Essigsaure, dann mit Wasser bearbeitet, wie die Uebrigen Proben gekocht und den weiteren Manipulationen der mechanischen Analysen unterworfen.

2 The loess was first treated with weak acetic acid, then, like the other samples, boiled in water. It was then subjected to the usual manipulation of mechanical analysis.

Horizons 4 and 6 present some noticeable characteristics. The latter, as is shown by its texture and cohesion in the soil profile is somewhat low in silt and especially low in clay. The former is highest of all in clay but is low in silt.

Since numbers 2 and 4, as is shown by the analysis, are similar, the latter rich in clay and poor in silt, the sand content in both is the same but the physical characteristics are dissimilar. It became necessary to investigate the clay constituent of both horizons in order to bring out the meaning of the figures in the table. We found that in horizon 4 the 27.25 per cent of clay consisted of

7%	0.01	-	0.005	mm.
2.75%	0.005	-	0.001	"
17.50%	0.001	-		"

and in the 22% of clay in horizon 2 there were

13.00%	0.01	-	0.005	"
2.25%	0.005	-	0.001	"
6.75%	0.001			"

Nearly 2/3 of the silt in horizon 4 (reddish brown) consisted therefore of the very finest particles while about 1/3 of the silt in horizon 2 is composed of the coarser particles. The silt constituent of horizon 4 is reddish brown in color while that of No. 2 is light brown.

The chemical composition of the several horizons expressed in percentage is as follows:

	2 %	3 %	4 %	6 %	7 %	8 %	9 %
Moisture	0.66	2.50	2.53	1.25	1.34	1.36	1.80
Loss on ignition	0.82	1.86	1.66	1.11	1.25	2.94	2.64 of which 1.20 was CO_2
SiO_2	88.23	82.57	80.44	87.70	84.06	80.82	79.63
Al_2O_3	7.37)		8.69	7.31)		7.18	6.73
	)	10.90		)	11.00		
Fe_2O_3	0.97)		4.03	2.11)		2.41	3.01
CaO	0.69	-	1.63	-	1.53	3.26	3.04 of which 1.54 was carbonate
MgO	0.49	-	0.78	-	-	0.88	0.63
K_2O	0.81	-	1.61	-	-	1.69	2.07
Na_2O	0.58	-	0.81	-	-	1.03	1.40
	99.96		99.65			100.21	99.15

According to this the reddish brown horizon shows the same characteristics as the corresponding horizon of the gray forest soils.

Horizon A_2 No. 2. compared with the parent rock and the other horizons produced by weathering is seen to be more thoroughly leached than any other horizon. In horizon 4 there is an important concentration of sesquioxides, a relative decrease of SiO_2 but no increase in the percentage of bases. In horizon 8, on the other hand there is an accumulation of lime but none of sesquioxide. When the large loss on ignition in this horizon and its dark color are taken into consideration there is a strong suggestion that the lime occurs in combination with organic matter.

Two conditions accompany and seem to be characteristic of the development of the reddish brown horizon, B, of this kind of soil (the Braunerde of Professor Ramann, soil from the vicinity of Budapesth, and the gray forest soils of European and Asiatic Russia[1] from Novo Alexandrija). They are:-

1 Glinka, Die erste agrogeologische Konference in Budapest, Pedologie 1908, No. 2, (Russian).

1. The participation of the forest vegetation in the development of the soils with reddish brown horizons;

2. The presence of lime carbonate in the parent rock.

In the temperate zone the forest vegetation determines the strong acidity of the soil solution, but the lime carbonate on the other hand neutralizes this solution and causes the precipitation of the dissolved iron compounds. Treitz[1] concluded, on the basis of observations made in Hungary, that a red soil rich in iron and poor in organic material always originated from calcareous rocks.

The following brief description of Braunerde is taken from Munteanu-Murgoci's[2] publications on Rumainian soils:- The Braunerde is in this region characterized everywhere by virgin oak forests and some other varieties of trees, the Podsol in Moldavia being covered with Beech forest and in Oltenia and Wallachia with mixed oak and beech. This brown to red soil contains from 3 to 5 per cent of organic matter, has a granular structure with angular granules; the soluble salts, including the carbonates, are leached to a depth of a meter or more. The angularity of the structure particles (which is in no sense a nut structure) is rather prominent in the subsoil and in this horizon the color is somewhat redder caused by concretions and coatings or iron oxide".

It is clear therefore that in the B horizons of all the known soils of the Podsol group, the carbonate of lime is to be looked upon as cause of the accumulation of iron. That can be shown by investigations in the laboratory if one leaches a lime carbonate bearing loess with a dilute solution of chlorides or iron. In the upper loess horizons hydrated iron oxide in colloidal condition begins to separate immediately and to color the horizon reddish brown. It does not take place however in loess free from lime carbonate[3].

With the change from European Russia to Western Europe, that is, with the rise of the mean annual temperature, an increase in the length of the vegetation period and increase in the number of occurrences of atmospheric precipitation, the processes effecting the decomposition of organic matter become more active, Podsol development seems fainter, and the reddish brown horizons become strong in their expression. The West European Braunerde is, so to speak, the last stage of acidic Podsol weathering and constitutes the transition to the Roterden and Terra-Rossa type of soil[4].

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1 Treitz, Aufgaben der Agrogeologie, Földtoni Közlöny, XL, 1910.

2 Munteanu-Murgoci, Die Bodenzonen Rumäniens. Comptes rendus de la premiere conference internationale agrogeologique. Budapest, 1909 S. 322.

3 Glinka, K., "Pedologie" No. 1, 1911.

4 We have already on a previous page pointed out that an occurrence of regradation is theoretically possible, that is to say that after the forest vegetation on any given spot has disappeared and

If we put together in one comprehensive scheme all that has been said of soils developed under conditions of average moisture conditions, the following scheme of classification results:

Podsolic Soils of primary origin.	Glei:	Podsolic soils or peaty podsolic soils. (Transition soils to those developed under excess moisture conditions.)
	Podsol soils. with hardpan- Podsol soils without hardpan	Individual varieties identified according to the degree of Podsolization. The leaching, mechanical composition and character of the parent rock.
Podsolic soils of secondary origin with reddish brown B horizon	Braunerden. Gray, laminated granular-soils, granular-nut structured soils. Degraded Tschernosem	Same as above

Geographically these soils are distributed over the Eurasian continent, in the following way:

North

Faintly Podsolized soils of northern European and especially of Asiatic Russia.

Decrease of temperature.

True Podsol soils of Western Europe.	More highly Podsolized soils of the southern part of the forest zone of this region.	decrease of rainfall.

Footnote 4 (continued)
grass vegetation has taken its place, a transition from forest soil to Tschernosem may take place. Some investigators maintain the existence of such processes but refer to no specific examples. In the solution of this question it seems to me that the reddish brown horizon of the steppe region becomes of great importance. When we can establish the existence of this horizon under the Tschernosem we shall have the right to claim that such Tschernosem is a secondary soil developed by regradation processes. Until such facts have been observed, we can do nothing more than admit theoretically the possibility of such processes and the change of gray forest soil into Tschernosem.

West

Rise of temperature decrease of rain-fall.

East

Braunerde of Western Europe.

Nut structured forest soils (in part Podsol soils) with thick humus horizons and decrease southward of the Podsolizing precesses.

Degraded Tschernosem.

Rise of temperature. Increase of precipitation.

South.

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17. Rispoloshenski, Beschreibung einer Sammlung von Bodenproben des Wolga - Kama- Gebietes. Kasan, 1896.

18. Sibirzef. Verhandl. der K. Freien ökonomischen Gesellschaft, 1896, Nr. 1.

19. Sibirzef, Verhandlungen des Institutes zu Nowo-Alexandria, 1899.

20. Slupski, E. Travaux de la Societe de Natural. de St. Petersbourg, 1899.

21. Sorokin, Verhandl. der Naturf. Gesellsch. bei Univ. zu Kazan, 31 Lief V.

22. Tkatschenko, Wälder des Nordens. St. Petersburg, 1911.

23. Truchanowski, der Landwirt, 1895, Nr. 23 u 24.

24. Winogradof, Nachricht der Petrowski - Landwirtschoftliche Akadem. 1903.

SOILS DEVELOPED UNDER MEDIUM MOISTURE CONDITIONS

The Tschernosem plays a predominant role in the history of Russian soil investigation.

Scientific and practical men devoted to pure and applied science have long interested themselves in this soil because (1) of its great agricultural importance, (2) its large area of occurrence, and (3) the characteristic conditions of its occurrence.

The origin of the Tschernosem, whence comes so great an amount of organic matter and why it is confined to a particular region, are questions which travelers, botanists, geologists and pedologists have sought many times to answer.

Lomonosoff was the first to attempt an explanation of the origin of the Tschernosem. Previous to 1900 however none of the Russian investigators concerned with the Russian Tschernosem knew anything of his work. Wernadski[1] first discovered anew for science, the paper of Lomonosoff on "Die Ersten Grundlagen der Metallurgie", published in 1763. "That the formation of this soil", said Lomonosoff, "is not mineralogical or geological, but belongs to the other two natural kingdoms, vegetable and animal, is understood by everyone".

Without any question the Tschernosem is not unchanged primary material but has been developed through the modification of an original material by the decay of animal organisms and vegetable remains. Even the Russian peasants arrived at this simple and natural conclusion long ago. Many of the Tschernosem investigators held, on the other hand, other views and discarded the popular idea.

Pallas[2] who traveled through Russia in the eighteenth century was the first observer to consider the Tschernosem as a marine deposit. He applied his hypothesis to the southern part of Russia only. In the investigation of the Stawropol steppes in northern Caucasia he noted the salt content of the soils and substrata of the region and concluded that the area was once a reed-covered swamp or a surface flooded from time to time by the sea in which a deposit of silt and clay rich in organic matter was laid down.

Murchison[3], the well known geologist, in extending Pallas' hypothesis to other regions than that to which it was applied by its author came to the conclusion that the whole Russian Tschernosem is

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1 Wernadski, On the importance of the work of Lomonosoff in Geology and Mineralogy, Moscow, 1900 (Russian)

2 Pallas, Bemerkungen auf einer Reise in die Sudlichen Staathalterschaften des russischen Reiches, 1799.

3 Murchison, Geological Description of European Russia, See also; Journal of the Minister of the Imperial Domain 1843, VIII, 119-138.

a marine surface deposit laid down in an extension of the Arctic ocean. In this connection it should be remembered that at that time glacial deposits were looked upon as arctic sea deposits.

In order to answer the question as to the origin of the organic material in which the Tschernosem is so rich, Murchison proposed a second hypothesis, according to which the Tschernosem is supposed to have been derived from black marine clay that had been carried far southward from the Arctic ocean. In his opinion this hypothesis would explain the geographic distribution of this soil in European Russia. Since there was no reason to suppose there ever existed any widespread deposits of dark colored clay north of Moscow there was no reason to expect the occurrence of Tschernosem north of the latitude of that place.

Somewhat later Petzhold[1] declared in favor of the marine origin of the Tschernosem which he looked upon as the silt deposit of a former larger and northwardly spreading Black and Caspian sea. The organic matter was supposed to have been derived from the remains of such animals as lived in the sea at that time. It was for that reason he thought that no plant remains could be identified. The high content of nitrogen was to be explained on the basis of its animal origin.

All these marine hypotheses appeared as the result of insufficient knowledge of the characteristics of the Tschernosem, its parent rock or its geographic distribution. At the present time they have historic interest only.

The hypotheses explaining this soil as originating in swamps are of more recent date. Until very recently some investigators barely separated the Tschernosem from soils developed under conditions of excessive moisture and frequently both kinds of soil, genetically so different, were united into one and the same group. The originator of this hypothesis in Russia seems to have been the scientist Eichwald[2] who considered the Russian Tschernosem as the product of former swamps and tundra. He based his hypothesis primarily upon his views as to the historical past of south Russia. In his opinion this region was once covered with forests and swamps. A secondary foundation for his hypothesis consisted in the occurrence of diatoms and phytolytarians, discovered by Ehrenberg, in some samples of Tschernosem.

Rupprecht had already stated that there was no reason to consider south Russia as heavily forested in ancient times since the Scythians and Sarmatians, in the time of Horodotus had complained of a scarcity of forests. The occurrence of Phytolytarians is not

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1 Petzhold, Beiträge zur Kentniss des Innern von Ruszland, Zunäxt in landwirtschaftliche Hinsicht, 1851.
2 Eichwald, Die Palaeontologie von Ruszland, 1850.

sufficient to support the hypothesis for they can develop from Stipa, a typical grass of the steppes, or from Graminifera.

Borissiak's[1] views were similar to those of Eichwald although the latter held that the identity of the Tschernosem with peat and humus was impossible. "The silty loam originating from the dessication of lakes and swamps could, under the influence of the change of climate and vegetation, become gradually dryer and looser and develop into Tschernosem".

Wangenheim von Qualen[2] who accepted the theory of the derivation of Tschernosem from peat, like the two last named investigators, postulated the development of the peat in other localities. Swamps and bogs occur mainly in northern Russia. He considered it possible that the silt and peat material was transported southward by inundations of the Arctic sea.

Ludwig[3], Romanowski[4], Tscherniaev[5],the latter accepting the marshy and in the main the aqueous origin of the deeper Tschernosem horizons, are all advocates of the swamp hypothesis.

Herman[6], who thought the Russian Tschernosem was very much like the marsh and swamp soils of western Europe, and Orth[7] who could not conceive of the Tschernosem as anything else but the product of excessive moisture conditions and who correlated it therefore with the moist meadow land soils, belong essentially to this group.

Gueldenstaedt[8] also,who in general stood for the land plant derivation of this soil came more or less under the influence of the prevailing opinions. In the same way Eversmann[9], Hoyt[10] and the unknown critic[11] of Petzhold's work held the same opinions.

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1 Borissiak, On the Tschernosem, Lecture, Charkow, 1852 (Russian).
2 Wangenheim von Qualen, Bull. de la soc. des natur de Moscou, 1853, p. 1, 1854, p. 1446. Verhandlung der Kaiserl. Freien Ökonom. Gesellschaft, 1854, Nr. 9 und 1875, 3.
3 Ludwig, Ueberblick der geol. Beobachtungen in Ruszland, insbesond. im Ural. Leipzig, 1862.
4 Romanowski, Bergjournal 1863, T. I. S. 484 (Russian)
5 Tscherniaev, Bull. de la Soc. des Natur. de Moscou, 1845, 18, Nr.3
6 Hermann, Landwirtschaftl. Zeitung der Landwirtsch. Gesell. in Moskau, 1837, Nr. 1.
7 Orth,Geognostische Durchforschung des schlesischen Schwemmlandes, 1872:- Die Schwarzerde und ihre Bedeutung fur die Kultur. Die Natur, 1877, Nr. 3.
8 Gueldenstaedt. Reisen durch Russland und im Kaukasisch. Gebirge. Herausgegeben von Pallas, 1787 - 1791.
9 Eversmann, Die Naturgeschichte des Gouvernements Orenburg, 1840.
10 Hoyt, Vogage, dans la Russie meridionale et la crimee, 1842.
11 P. A. Zeitschrift des Minister, der Reichsdomänen 1852 - 1853 XLIV, Bibliogr. 12 - 14.

The academician Rupprecht[1] must, as Dokutzchajeff rightly remarks, be looked upon as the originator of the thorough going scientific work which finally solved this problem. He attacked it from the botanical standpoint. At the beginning of his classical work on this soil he wrote, "The Tschernosem question is a botanical question". He discarded the hypothesis of its origin as marine sediment or as peat. Neither did he accept the view of its origin as due to forest vegetation since he found in the Russian steppes no forests and the microscopic examination of 300 Tschernosem samples made by Weisse[2] and collected from 30 widely separated localities had shown the absence of the remains of tree roots.

At the present time the presence or absence of such could be considered unessential and the defender of the former existence of forest could with justice maintain that the time elapsed since the destruction of the forests has been sufficient for the change of all tree roots into structureless organic matter.

Viewing it from all sides this investigator draws the conclusion that the Tschernosem has developed from steppe grass vegetation and is a land plant soil wholly analogous to the grassy soils of northern Russia. The latter differ from the Tschernosem through their lighter color and the thinness of the darker colored layer. The difference between these soils was based not only on differences between the respective floras but also the differences in age. He denied the influence of climate entirely.

Although Rupprecht's solution of the Tschernosem problem is somewhat one sided, yet his services in this respect were great. He was the first scientist to discuss thoroughly the theory of the land-plant origin of the Tschernosem and to discard the marine and moor hypotheses of origin. The theories were not wholly demolished by him, for long after his time the Tschernosem was looked upon as a moor soil or at least one developed under conditions of excessive moisture, though the views held were not identical with those of Eichwald and Wangenheim von Qualen. Rupprecht's further view that the formation of the Tschernosem under forest was impossible was subjected to criticism. Bogdanoff[3] who in general supported the views of Rupprecht held that some influence from forest vegetation was not necessarily excluded, but that this question had not been sufficiently investigated. He thought that in forests larger amounts of organic remains were accumulated than in regions of the poor vegetation of the dry steppes. Under the forests of the Province of Simbirsk and Saratow he found a soil which according to him could not be distinguished from Tschernosem.

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1 Rupprecht, Geo. botanische Erforschungen des Tschernosems, Beilage fur den X B. Bericht der Kaiserlichen Akademie der Wissenschaft Nr. 6, 1866.

2 Weisse, Bull. de la Soc. des Natural. de Moscou, 1855.

3 Bogdanoff, Vögel und Tiere der Tschernosemregion des Wolgalandes, St. Petersburg, 1872. Arbeit der Kaiserl.-Ökonomisch. Gesellschaft, 1877, 1.

Since Rupprecht had not worked out his subject with sufficient detail, the origin of the humus in Tschernosem, even by those who regarded it as of landplant development, was still given an explanation different from that given by him.

The academician Karpinski[1] held that the character of the parent rock had a predominant influence; Tschernosem is characteristic of the loess region and when an organic soil develops on a rock which has the characteristics of loess it is Tschernosem or a soil similar to it[2].

According to Stuckenberg the Black Earth in southeastern Russia occurs in the region where the highly alkaline sediments of the Caspian sea are absent. In the latter the Artemisia steppes are widely distributed. North of the Caspian sea deposits the Stipa steppes first appear and along with them the Tschernosem soils.

The views of Professor Schmidt[3] of Dorpat are unique. He regarded the connection between the origin of the Tschernosem and that of the parent rock as very close. He took into consideration the inorganic constituents only and compared their composition with that of the crystalline rocks of Finland and those on the Dnieper. He arrived at the conclusion that the mineral constituent of the Tschernosem was more like that of the granite of the Dnieper than like that of Finland and that the Tschernosem, like its parent rock, was derived through weathering from the granitic rocks of the Dnieper. At the present time such hypotheses seem wholly without foundation so that it is not necessary to consider them further.

From the above references it is evident that in spite of Rupprecht's evidence of the landplant origin of the Tschernosem, the problem was not yet completely solved.

The matter was finally cleared up by Dokutschajeff who published in 1883 his fundamental work, "The Russian Tschernosem". In doing this he had to answer the following questions:-

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1 Karpinski, Wissenschaftl. - Historisch. Sammelwirk d. Berg-Institutes, 1873.

2 Kontkiewicz (Geol. Untersuch. im Granit Gebiet Neu Russlands, am linken ufer d. Dnieper, 1881,) and Agapitow (Nachricht d. Ost-Sibir. Abteil. d Kaiserl. Russ. Geograph. Gesellsch. XI, 3-4) discussed later the important role played by the loess deposits in the Tschernosem question. As is well known Professor Hilgard even at the present time thinks that Tschernosem can develop only on rocks carrying carbonate of lime.

3 K. Schmidt, Physikalisch. - Chemische Untersuch, der Böden und Untergrunde des Tschernosemgebietes d. Europaisch. Ruszlands., Lief. 1, 1879.

1. Can Tschernosem be developed under forest conditions?

2. Is the presence of loess of any kind necessary for the development of this soil?

3. Has the climate, as Rupprecht says, really no influence on Tschernosem formation?

The first question was answered in the negative by Dokutschajeff as it had been by Rupprecht also, partly on the basis of his own observations and partly on the conclusions of Lyell and Lewakowski. Lyell was of the opinion that even in forests as high and dense as those of tropical Brazil and occupied like them by an untold number of animals, birds and insects, would after ten thousand years accumulate a humus layer but a few inches thick. In the investigation of the Crimea Lewakowski found that in the forests which since ancient times had covered certain areas not only had no Tschernosem developed but no important humus accumulation had taken place.

From the standpoint of soil investigation these examples from Brazil and the Crimea have very little value for along with the question of the forest influence on Tschernosem development the influence of climate must be taken into consideration. Conclusions as to the influence of forest based on facts selected at random from any locality at will cannot have any direct bearing on the matter. Only those forests existing within the Tschernosem zone can have direct value as evidence in the matter. Through the study of the forest soil in the Tschernosem zone Dokutschajeff convinced himself of the fundamental difference between the characteristics of this soil and those of Tschernosem. Although Tschernosem may be seen under forests in the Tschernosem zone, a fact already mentioned by Bogdanow, yet that does not prove that it was developed under forest conditions. Forests may become established on a Tschernosem that had been in existence for a long time previously.

It seems to me however that in his studies Bogdanow did not recognize at all the signs of degradation in the Tschernosem lying under forests, signs which one can find very easily at present.

Theoretical considerations relating to the decomposition and accumulation of forest remains caused Dokutschajeff to deny the possibility of a development of Tschernosem under forest cover. The importance of climate was stated by this investigator as follows:- "The influence of the climate (in soil forming processes) is many sided: it influences (a) the type of flora (Steppe flora, northern meadow-flora, etc.) (b) the annual increase in accumulated vegetable matter, (c) the annual amount of decomposition of plant materials (on the surface as well as in the soil) and (d) the character of the decomposition processes (acidic or otherwise). Soils from widely separated places with the same physical characteristics, in which however the conditions stated under b, c and d,

vary, are not identical. Dokutschajeff finds that the first condition is not of very great importance in spite of its close relation with the others. "Take for example" he writes "several areas with uniform soil and subsoil, uniform relief and uniform age, and allow them to be covered within the same time with the same kind of plant cover. Place one of them in a part of Russia where the rainfall is low, the summer long and the winter short, where the vegetation process is energetic but slow, where the wind is dry and in two or three days all streams dry up, the vegetation dies, where forests are absent, where surface streams are few and evaporation is rapid. Place the other area in a part of Russia which has an excess of moisture, cool short summers, winters lasting from 6 to 7 months, the summers from 3 to 4 months, the evaporation small, the soil more or less wet permanently, and where forests and swamps exist. Place a third area in that part of Russia where the existing climatic conditions are intermediate between those of the two areas already cited".

These areas whose climatic conditions have been selected as examples are similar to (a) Those lying furthest south and southeast in Russia, (b) Those in northern Russia, and (c) Those in our Tschernosem zone. Between them there are transitions. That the same soil could develop under such widely different conditions is impossible.

Although Dokutschajeff has described so well the climatic conditions of the most southerly region, his description of the northern is less thorough since the excess of moisture here is known to exist only in low places. Yet in both these the data is sufficient to enable one to discuss easily the energy and character of the decomposition processes. The climate conditions of the Tschernosem zone however are still rather imperfectly known.

In the north the excessive moisture permits the accumulation of organic remains in the form of peaty mosses and of incompletely decomposed swamp accumulations. In the southern region humus can not accumulate in large amounts while in the Tschernosem it accumulates in considerable amounts but its characteristics are entirely different from those in the northern area. Dokutschajeff does not explain the cause of the accumulation of organic matter in the Tschernosem, but from his short discussion one can easily conclude that it can not be due to excessive moisture. His opinion that the climate of the Tschernosem region was essentially the same during the development of the soil as it is now is of especial importance since the existing conditions cannot be considered as moist. Temperature and moisture of the steppes suffice for the production of an abundant growth of grass but not for rapid and energetic decomposition of the organic material. It must accumulate therefore.

Similar views were held by Middendorf[1] also. Dokutschajeff considered that his theory of the importance of climatic influence on the geographic distribution of the continental humus soils in European Russia was established mainly by the following facts.

1. The Tschernosem occurs as a broad northeast-southwest belt parallel to the isotherms rather than to the parallels of latitude. It corresponds also to the distribution of rainfall and to that of certain kinds of wild grass and forest vegetation.

2. The individual humus zones of the Tschernosem follow the same direction.

3. Along the mid-zone of the Tschernosem belt the soil holds a maximum of humus. From this zone outward in both directions perpendicular to the trend of the belt the content of humus decreases gradually to the Tschernosem boundary.

4. In places a change in the native vegetation coincides with the gradual disappearance of the Tschernosem characteristics.

The highest humus content, according to Dokutschajeff is found in the eastern part of the central Tschernosem region. Northward and southward from this zone the humus content decreases gradually. The successive parallel belts are called by Dokutschajeff Isohumus belts.

Later, thorough investigations show that the distribution of humus in the Tschernosem of European Russia is not so regular as Dokutschajeff thought. In general however his statement is true for without doubt there is a decrease in amount both northward and southward from the line of maximum content, but along with it there is a corresponding change in humus character. Both changes must be ascribed to the influence of climatic conditions. On the other hand the humus content will be strongly influenced by the mechanical constitution of the parent rock since it is the latter that determines the greater or less water and air penetrability of the soil and in this way a rapid or slow decomposition of the organic matter.

Rupprecht observed long ago that Tschernosem is not formed on coarse sand, that is to say no massive humus horizon is formed, though he did not base the statement on world-wide observation.

The humus content is higher in the Tschernosem of East Russia than in that of the western part of the country, a fact ascribed in later years by Dokutschajeff[2] to differences in the mechanical composition of the parent rock in the two regions.

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1 Middendorf. Skizze des Ferganatales, 1882.

2 Dokutschajeff, The Russian Tschernosem, 1883 (Russian)

That rocks having the characteristics of the loess are not the determining factors in the existence of the Tschernosem is shown by the fact that Dokutschajeff identified it on Jurassic clay and chalk, chalk marl, Devonian Limestone, Tertiary loam and sands. Like every other soil type therefore it may be developed on the most varied parent materials.

In closing our general glance over the theories dealing with the formation of the Tschernosem the statement of Krassnow[1], dealing more however with the origin of the steppes than with that of the Tschernosem, will be mentioned. For the formation of steppes he postulates an even surface, poorly drained, having sufficient excess of water to be harmful to the roots of trees. Salts, which have not been leached out of the soil because of the lack of drainage act in the same way on tree roots. The undrained steppes are designated by him as primary. To these belong those lying on the Black sea and along the Dnieper, the steppes of Boraba, the prairies along the middle course of the Amur river, the greater part of those in the region of the Great Lakes, the Llano Estakado and in part also the Hungarian Pouszta. The dissection of the steppes by streams or the formation of underground drainage ways changes them. They become covered with forest trees and constitute a transition from true steppe to true forest.

We cannot accept Krassnow's views, for steppes are by no means all level and this characteristic cannot therefore be considered typical. Steppes are known to occur in the mountains of Transcaucasia, in Transbaikalia, in the region of Semipalatinsk and Akmolinsk on which the relief is rolling and hilly. Notwithstanding this uneven topography they are covered with grass vegetation and with Tschernosem and Chestnut Colored soils. On the other hand there are large areas in the Podsol zone of European and Asiatic Russia in which the topography is smooth. It is impossible also to place the prairies of the Amur river region, those on the Dnieper, and the Hungarian Pouszta in the same group. According to Schimper, the Amur prairie is not a steppe but a flat, poorly drained area and the soil covering it has nothing in common with the Tschernosem. The steppes of the Dnieper are covered with Tschernosem and the Pouszta of Hungary mainly with Chestnut Colored soil.

It is possible[2] that our steppes were, not many centuries ago, more moist, especially in spring, than the present cultivated and somewhat dissected surface but without question there was no excess of moisture. Such excess would have influenced not only the rate of decomposition of the organic matter but also the soil chemistry and morphology. It would have given to the soil a series of characteristics that could have been recognized at a later period, none of which are found in the Tschernosem at the present time.

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1 Krassnow, Die Grassteppen der Nördlichen Halbkugel. Moskau, 1894.

2 Ismailski, Auf welche Weise unsere Steppe trocken geworden ist. Arbeit der landwirtschiftliche Gesellschaft zu Poltawa, 1894.

If sufficient material for the formation of humus be present its accumulation will take place not only in the presence of excessive moisture but also where moisture is deficient. Even if the Tschernosem steppes could be regarded as having had formerly excessive moisture, the Artemisia steppes with well developed Xerophytic vegetation could furnish no evidence of such condition. On the northern border of the zone however, the soil contains five percent or more of humus.

Throughout the period of time during which the origin of the Tschernosem was under discussion and investigation its distribution also was being studied. The first works dealing with this matter were published in the 19th century by Storch[1] and by Georgi[2]. According to these descriptions, based in part on the work of the land surveys, the Tschernosem is found in the province of Novgorod-Ssewersk, in the southern part of the states of Tschernigov, Kiev, Ekaterinoslav, in the northern part of the region of Otschakow, in the region of the Don Kossacks, in certain steppe regions of the Crimea in the provinces of Charkow, Kursk, Orel, in some parts of the provinces of Tula and Kaluga, in the southern part of the province of Simbirsk, Pensa, Tambow, Woronesh, Saratow, Kasan, Nishni-Novgorod, Ufa, Wiatka and Perm. Although mistakes of omission and commission are undoubtedly committed in these descriptions, yet this sketch of the distribution of the Tschernosem is in general full and correct. These descriptions were used, with certain changes, as the basis of the industrial map of European Russia which appeared in 1872. In the Crimea, on the left bank of the Don, in the regions of Tersk and Kuban the occurrence of the Tschernosem is not mentioned.

In 1851 a soil map of Russia was published by the Minister of the Imperial Domain under the direction of Wesselowski[3]. It was based on data which the minister had accumulated from 1838 to 1843 working in cooperation with the Commission on Land Surveys, the Holders of the Imperial Domain, some correspondents of the Commission on Education and others. In constructing the map all existing literature on the subject was utilized. On this map the Tschernosem of the Caucasus is not indicated, but in its place some Tschernosem islands are shown which do not exist (on the West Duna for example). This map, without any change, was republished in 1853 and again in 1857. In 1866 a map showing the distribution of the Tschernosem was published as a supplement to Rupprecht's book, "Geobotanical Investigation of the Tschernosem". On this map, in addition to the

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1 Storch, Statistische Uebersicht d. Statthalterschaften des russischen Reiches, 1795.

2 Georgi, Geographisch - Physikalische und naturhistorische Beschreibung des russischen Reiches, 1797.

3 Wesselowski. Agricultural Statistical Atlas of European Russia, 1851. The Climate of Russia. Russian Academy of Science 1857 (Russian).

unbroken Tschernosem zone which breaks up along its northwestern border into a number of islands, an additional number of islands is shown extending along its northern boundary, in the provinces of Tschernigow, Kaluga, Wladimir and Kasan. In 1867 a new edition of the map was published under the editorship of Wilsson[1]. It differed from the earlier editions in the details of its northern and southern boundaries and in showing an additional number of border islands.

In 1879 a soil map of Russia was published under the editorship of Tschaslawski on which the Tschernosem boundaries differed somewhat from those on preceding maps. In the Caucasus the Tschernosem is shown for the first time and the Russian Tschernosem was separated into eight varieties. In 1882 Dokutschajeff published a map showing the distribution of this soil in European Russia and in 1883 it was issued as a supplement to his book "The Russian Tschernosem". On this map the belt is separated into several isohumus zones.

Finally another soil map of European Russia was published in 1901 by the Minister of Agriculture and The Imperial Domain, based on Dokutschajeff's ideas and prepared by Sibirzeff, Ferchmin and Tanfilieff. Ferchmin used this data in the preparation of a soil map of European Russia published on a scale of 1:9,030,000.

The northern Tschernosem zone covers an immense surface in European Russia and extends thence eastward and westward. The influence of mountain chains on its distribution (the law of vertical distribution) is shown both to the east (Ural) and south (Caucasus) of the main European area. In the southern districts of Saratow the Tschernosem fails and its place is taken by the soils of the desert steppes. The latter is replaced again, on the lower slopes of the Caucasus, by the Tschernosem. The Tschernosem zone is broken in the Urals, its place being taken by Podsol soils. The Altai and other mountain ranges of Siberia act in an identical way on the Siberian Tschernosem belt. The Siberian zone, almost unbroken for a long distance east of the eastern foot of the Urals, breaks up into isolated areas as it approaches the lower slopes of the Altai mountains. In eastern Siberia it is still more completely broken up into islands by the various ranges of Eastern Siberia (Jenesseisk, Irkutsk and Transbaikalia).

The most easterly of the Tschernosem islands of Russia are found in the vicinity of Srietinsk and Nertschinsk in Transbaikalia. From Transbaikalia the zone passes into northern Manchuria, though it does not extend as far east as the Pacific. It does not occur at all on the Amur or in the Coast region.

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1. Wilsson. Text accompanying the Agricultural Statistical Atlas of European Russia 1869 (Russian).

In Asia the Tschernosem of western Siberia is more or less well known. The expeditions under the direction of the office of Colonial Affairs, which have been investigating the soils of Asiatic Russia for the last five years have been concerned mainly with the soils of other soil zones and only very recently has the investigation of the Tschernosem been taken up. The members of these expeditions encountered the soil along the line of Trans-Siberian railway[1] in the Altai[2] region and in the province of Tobolsk.[3]. Very recently the Tschernosem of Eastern Siberia has been studied in certain parts of the province of Jenisseisk[4] and the steppes of Nertschinsk.[5]

According to Gordiagins the Tschernosem of the Tobolsk province does not occur in continuous bodies over any considerable area of country. It lies in long narrow but low gently swelling ridges with a northeast and southwest trend. Between them lie soils of other types which are fully described in the section dealing with the geography of Russian soils. In the southern districts of Kurgan, Ischim and Tükalinsk, the Tschernosem covers large areas of smooth steppes. Gordiagin mentions that the groundwater lies at considerable depth beneath these steppes and that only a small amount of moisture is present below 6 feet and above 12 feet below the surface. In summer the soil at a depth of 6 feet is dryer than on the surface. The snow disappears early and melts rapidly on the smooth plains. The rainfall does not penetrate to any considerable depth. This fact shows that the west Siberian Tschernosem does not develop in the presence of excessive moisture. It occurs in part of the province of Tomsk and has developed under the same conditions as those described above.

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1 Wyssotzki, Geolog. Erforsch. in der Tschernosem zone von Westsibierien. Bull. du Comite Geol. St. Petersb. T. XIII.

2 Wydrin und Rostowski, Material zur Erf. der Böden der Altairegion und der Umgenbung V. Barnaul, 1896. Smirnoff, Die Arb. d. Expedit fur Bödenuntersuchungen. Lief. 1, 1909.

3 Gordiagin, the work of the Natural History Society of Kazan, 34, 1900. (Russian)

4 Vorläufige Bericht der Organisation und der Ausführung der Arbeiten bei der Erforschung der Böden des asiatischen Russl. im Jahre 1910 unter der Abfassung von K.D. Glinka: Bericht von Prassoloff. Altere Angaben ueber die sibirische Tschernozem-zone siehe bei Martjanow. Arb. der Naturforschenden Gesellschaft zu Kasan, 11, Lief. 3 und Berichte der Kaiserl. russisch. Geograph Gesellschaft, Ostsibirische Abt. 14, 1-3. Agapetoff, Berichte der ostsibirische Abteilung der Kais. russische geographische-Gesellsch. 11, 3-4. Jaworowski, Bull. du Comite Geologique St. Petersbourg, T. XIV.

5 At the present time this region is being geologically and botanically investigated by Sukatscheff.

West of the Russian Tschernosem area the soil is found in Galicia where it has been studied recently by Buber[1] and it is known to occur also, in Hungary. The boundaries of the Austro-Hungarian Area have been shown by Lorens, on his soil map. It is now known however that by no means all of the Hungarian Pouszta belongs to the Tschernosem belt. An important part of it is covered by Chestnut Colored[2] soils and has been shown as such on the most recent Hungarian[3] soil maps. Of the west European Tschernosem areas those of Bulgaria and Roumania[4] must be mentioned, as well as those in Germany, especially those in the vicinity of Magdeburg and Hildesheim[5]. The latter is mainly degraded Tschernosem. The zone does not reach the Atlantic Ocean since moist oceanic winds prevent the development of continental soil zones on the coastal lands. On the coastal belts of the Atlantic and Pacific Ocean there is a gradual transition from the soils of the forest covered Podsol zone in the far north to those of the yellow and red soils of the warmer latitudes of the south.

In North America the Tschernosem occurs in Dakota, Nebraska and Texas. The soils of the prairies of the Mississippi are apparently similar to the meadow or wet land soils on the Amur river and lie there, as on the Amur, immediately east of the Tschernosem.

In South America, Black Earth is known to occur in Argentina where its western boundary lies along the 67th degree of west longitude (Paris) its southern along the 38th parallel, while its northern boundary lies on the Salado river in latitude 30. The best developed Tschernosem is found in the province Entre-Rios. In Santa Fe it is thinner and westward it becomes sandy. In the province of Cordoba it is found in the eastern part and west of that it becomes gradually replaced by sand. In Buenos-Aires it is best developed in the northern part. Southward and southwestward the loamy Tschernosem becomes sandy, and gradually passes into sand. The conditions under which it develops in Argentina correspond in general to those of the European Black Earth region. We have no knowledge of the existence of the soil in other places in the Southern Hemisphere though its occurrence in South Africa and Eastern Australia is not impossible.

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[1] Buber, Die Galizisch.-podolisch Schwarzerde, ihre Entstehung und natürliche Beschaffenheit und die gegenwartigen landwirtschaftlichen Betriebsverhältnisse des Nordostens dieser Bodenzone Galiziens Berlin, 1910.

[2] Glinka, K. Die erste agrogeolog, Conferenz. in Budapest. Pedologie, 1909 Nr. 2

[3] Treitz, Was ist die Agrogeologie, Földtani Közlöny 1910.

[4] Murgoci, G. Comptes rendus de la premiere conference agrogeologique, Budapest.

[5] Nikitin, Bulletin of the geological committee of St, Petersburg, 5, 1896. Sibirzeff, Report of the Institute of New Alexandria, 12, 1899. Bogoslowski, Pedology, 1902, No. 4 (Russian)

No important evidence of the occurrence of Tschernosem in the tropics has so far been discovered. Theoretically it is possible that along the zone where the moist subtropical region grades into the subtropical semi-arid belts grass covered areas will be found in which both temperature and moisture conditions are such as to cause the accumulation of vegetable matter as in the Tschernosem steppes of Russia. The possibility however cannot yet be stated as a fact. It is not possible to identify the Indian Regur as equivalent to the Eurasian Tschernosem on account of insufficient information concerning its profile. The history of the investigation of this interesting soil is like that of the Russian Tschernosem. In the description of the land survey of Madras by the Geological Survey of India, this soil is variously designated as Regur, Regar, Regada and Cotton Soil. It is doubtless true, as was the case with us in regard to the Tschernosem, that every dark colored soil has been designated as Regur by the geologists and they have not interested themselves in the conditions of their origin or morphology[1]. Newbold considered it a water laid deposit which once covered a large area. King[2] compared it with the peat moors of Ireland, with the black soils of the forests of Annam and the bogs of the Nile, notwithstanding the fact that from the Regur locality every trace of swamp or forest has disappeared. Foote and Walther[3] entertain similar views. Other investigators attribute its dark color to the dark colored volcanic rocks from which it is derived.

Woejkow[4] and Von Richthofën[5] have both discussed the relationship of the Tschernosem to the Regur and their similarity of origin. The samples from India which were used by Woejkow has apparently not become typical Tschernosem and on this basis Dokutschajeff considered the Regur as not true Tschernosem. The structure of the Regur, briefly described by Richthofen is the most reliable information we have for forming our opinion on the relationship of the two soils. Richthofen mentions the occurrence of lime concretions beneath the dark colored surface horizon. He states also that (1) The regions in which the Regur occurs are covered with tall grass, (2) It carries no forests, (3) The annual precipitation is less than 48 inches and (4) There is a well defined rainy season and a well defined dry season and the change from one to the other is rapid.

It is well known that in the Tschernosem zone of Argentina where the mean annual temperature is 16 to 17 degrees centigrade, the rainfall amounts to as much as 32 inches. Theoretically therefore a combination of about 40 inches of precipitation and

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1 Woejkow, Tschernosem in Indien. Arb. der Kais. Freien Oekon, Gesell. 1880,3.

2 King. See Woejkow.

3 Walther. Lithogenesis der gegenwort. Jena 1893-94.

4 Woejkow, ibid.

5 Von Richthofën. Fuhrer fur Forschungsreisends, 1886.

5 to 28 degrees cent. annual temperature, like that which exists n the Regur region would produce approximately the same or imilar results in soil making.

In addition to the large areas which the Tschernosem covers n the great plains of the two hemispheres it occurs also in mounain regions as one of the members in the series of vertical soil ones which are found in such regions. The height at which it lies s determined by the climatic conditions at the foot of the mounain on which it occurs. If the foot of a mountain is covered ith forested Podsol soils no Tschernosem will be found on the ountains. If the mountain rises from a desert or a desert steppe n the other hand, Tschernosem will occur at some level above, in ase the height of the mountain is sufficient. For example, the schernosem is absent entirely from the mountains of Europe; on the ther hand it is of frequent occurrence in the mountains of Transaucasia (in Tiflis and Eriwan) where it was seen and studied by okutschajeff[1] and Sacharow.[2] It has been identified by Krassnow[3] n the mountains of Turkestan in 1887 but was not fully investigatd until recently, when it was studied by the expeditions of the ussian Emigration Administration.[4] Its occurrence is possible on he slopes of the Pyrenees, in the Atlas mountains and elsewhere in imilar situations.

The Tschernosem soils of European Russia have been separated nto a number of varieties on the basis of the thickness of the umus horizon, the amount of humus they contain and their morphoogical characteristics. They are: 1. Northern Tschernosem; 2. rdinary Tschernosem; 3. Fat or thick Tschernosem, and 4. Southern 'schernosem[5].

The morphological characteristics of the Fat Tschernosem are as ollows: The thickness of the humus horizon (A_1 plus A_2) will each an average of about 40 inches[6], of which the upper of A_1 horizon will constitute half or more. The horizon A_1 is uniformly

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1 Dokutschajeff, Preliminary report on the Investigations in the Kaukasus region in the summer of 1899, Tiflis, 1899. (Russian).

2 Sacharow, Pedology, 1906, Nr. 1-4 (Russian)

3 Krassnow, Arb. der Naturforsch. Gesellschaft zu St. Petersburg, 1887.

4 Glinka, K. On the question of the classification of the soils in Turkestan. Pedology, 1909. No. 4. (Russian) Neustruew, Work of the Expeditions sent out to study the soils in regions selected in Asiatic Russia for colonization. 1908, Part VII (Russian) Bressonow. Part VI (Russian)

5 Sibirzeff, Bodenkunde, III Teil. - Tumin, Arbieten der Boden-expeditionen zur Erforschung der zu Kolonisierenden Region des asiatischen Ruszlands. Bodenforschung, Lief, 10, 1910. The characteristics of the Tschernosem as given in the text are taken from these publications.

6 These figures apply to the loams. In the sandy types the thickness of the humus horizon is greater.

olored and in the loams and silt loams, is granular in structure. he transition to the A_2 horizon is gradual, so that it is diffi-ult to draw a boundary between the two. The A_2 horizon is like-ise uniformly colored though there is a gradual change downward o a lighter color, and in the lower part there are faintly eveloped streaks and spots. The upper part of horizon A_2 is gran-lar in structure, changing downward to a nut structure and still ower into a prismatic lumpy structure. In the sandy types no tructure can be seen and the humus horizons are loose.

In ordinary Tschernosem (Fig. 10) the thickness of the humus orizons (A_1 plus A_2) reaches an average of about 28 inches, of hich the thickness of the A_1 horizon is less than half, and often nly a third. The transition from horizons A_1 to A_2 is more abrupt han is that in the Fat Tschernosem. Horizon A_2 is spotted and treaked, dark spots and tongues alternate with tongues and spots of aterial like the parent rock. In the loams and silt loams horizon 1 is granular, but the structure is faintly developed. It is some-imes lumpy, the lumps break up however into granules. In horizon 2 the granular structure becomes nut structure and this passes nto a lumpy prismatic structure below. In the upper 5 to 10 centi-eters Horizon A_1 is marked by a faintly developed platy structure, hough it disappears under cultivation.

The most striking characteristic of the Southern Tschernosem is he grayish shade in its color. The black background however is asily recognized. The same color shade is characteristic also of he Chestnut Colored soils but in the latter the fundamental color s brown rather than black. The thickness of the humus horizon of he Southern Tschernosem ranges around 25 to 28 inches of which the 1 horizon makes up from 4 to 8 inches. The A_1 horizon is strik-ngly arranged in layers has a fine granular or gunpowder-like tructure, the diameter of the granules ranging from half to 1 mm. nd the transition to horizon A_2 is abrupt. Horizon A_2 has a well eveloped spotted and tongue-like color distribution. The upper hird to half has a granular structure but the granulation passes nto nut structure downward and still lower into prismatic lump tructure. The humus horizons in the field are slightly compacted, re broken with vertical cracks and can be removed as prismatic umps or clods. The clods of horizon A_1 fall readily into granules bout the size of gun-powder grains, and the upper part of horizon 2 into granules about the size of peas.

The morphology of the northern Tschernosem has not been horoughly studied. It has usually a grayish shade, approaching he color of the Podsol type. Horizon A_1 has a platy or lamellar tructure and horizon A_2 is not uniformly colored.

In addition to the foregoing morphological characteristics the ccurrence of lime carbonate and gypsum accumulations in the lower umus horizons is a common characteristic of all varieties. Effer-escence with acid does not occur in the upper horizons, beginning

usually in the lower part of the A_2 horizon. In the southern Tschernosem effervescence often takes place on the surface though this phenomenon is due to the lime content of the parent rock and not to existing soil forming processes. The presence of lime carbonate in the lower horizons is due however to the action of existing soil forming processes. This is shown by the fact that it accumulates not only in Tschernosem that has been developed from carbonate bearing rocks but also from that developed from granite, Basalt or other kinds of rocks.

On the surface of the virgin Tschernosem there is often a vegetable covering or sheet like a dry sponge consisting of fine clay[1] sand and roots. According to Dokutschajeff's observations in the Strukowski Steppes of Poltawa the surface is covered in places with a brown pulverulent decaying organic mass like a soft carpet (Dry Peat).

To the characteristic features of the Tschernosem profile belongs also the occurrence of passage ways of burrowing animals, called by the Russians Crotwines. They appear in the soil profile as oval or irregular formed spots which can be seen in the humus horizon only when they are filled with the lighter colored parent rock or in the latter only when they are filled with material from the humus horizon.

There has been a great deal of discussion in Russian soil literature of the origin of these Crotwines. One group of authors maintained that they are animal burrows filled with soil or soil material while another group maintained that they are the filled cavities made by tree roots[2]. They were separated by Sukatschef[3] into four groups as follows:

1. Crotwines which consist of more or less uniform material appearing in the soil profiles as unbroken circles or varicolored ellipses. In the humus horizons they appear as yellow spots while in the parent rock they appear dark. To be sure they can occur where the filling material is exactly like the surrounding material but in such cases they can not be seen until masses of the filling material have fallen out in such a way as to preserve its characteristics as a cast of the hole.

2. Crotwines which consist of two cylinders one lying within the other. They form in profile a disc surrounded by differently colored rings. In the parent rock the latter is darker than the mass of the filling material while in the humus horizons it is lighter. The outer ring is usually more dense, harder and richer

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[1] Polenow, Angaben zur Bodenwertschätzungen des Gouvernement Poltawa,(Kreise Chorol.) 1890.
[2] Dokutschajeff, Der russische Tschernosem, 1883, S. 175.
[3] Sukatschef. Pedologie, 1902, Nr. 4.

in lime than either the filling material as a whole or the surrounding soil. If the ring is thick it has usually a layered structure. Occasionally Crotwines are found only half surrounded by a ring.

3. Crotwines which are either concentrically or excentrically built up of layers or rings and in the soil profile appear as circles or ellipses. In the mass of material filling the hole there are concentric and excentric streaks. The filling material does not differ from the surrounding material either in color or density. The excentricity may be seen when the plain of the soil profile does not lie perpendicular to the length of the Crotwine. This kind is of rare occurrence.

4. The last form does not constitute in reality a distinct type. They consist of forms that combine the features of the first two types through the inclusion of one within another and when they cross each other in the profile.

According to Sukatschef[1] the Crotwines are uniform throughout, without characteristic structure of any kind when the filling has been effected mechanically through the action of rain water or by the animal formerly inhabiting it. In the former case carbonate secretions will be found on the walls, in the latter the animals will leave behind fatty matter, remains of food and excrement, all of which are mainly organic in their nature, and will decompose into humus. That the Crotwines are often only half surrounded with lime carbonate may be explained as the result of caving or the presence of food remnants or animal excrement. The stratified ones are hard to explain, apparently however water has participated in their formation.

The investigation of the deep horizons of the Tschernosem has shown that faintly developed humus horizons are often found in the loess region at depths of 7 to 10 feet. They are associated with accumulations of lime carbonate and gypsum. In the accompanying figure taken from Wyssotzki's Pedologie, the humus-gypsum horizon is marked by the letter F. It lies about 8 feet from the surface as can be seen by consulting the figure. Tongues or streaks of dark color extend upward and downward from the upper and lower surfaces respectively. Gypsum occurs in the form of small crystals or of rather large concretions ranging from nut size to egg size. Often the gypsum horizon lies above the humus horizon and at other times it is absent entirely. In the secretions of lime carbonate the following has been noticed: The upper Tschernosem horizon, usually about 18 inches in thickness contains no noticeable accumulation, nor does it effervesce in acid. At greater depth lime carbonate appears in the form of streaks which occasionally are similar to the mycelium of fungi in appearance and as streaks and concretions. The lime carbonate begins to appear usually at about 32 to 36 inches in the form of roundish spots. The second horizon lies at a

[1] Sukatschef, Pedology, 1902, No. 4 (Russian).

depth of about 4-1/2 feet and the carbonate consists of isolated hard lumps and whitish irregular spots. In the intermediate horizon E and that part of the humus horizon marked by "f" there are very few concretions. Wyssotzki states that the formation of an upper lime carbonate horizon is brought about through the rise of the soil moisture in summer when it has the maximum lime carbonate concentration. The solutions do not reach the surface however because the moisture is absorbed by plant roots. At this depth secretions of other salts take place, accumulating in the small pores, cells, the nests and passage ways of small animals.

After Wyssotzki had studied the Tschernosem profiles of Welsko-Anadol in the province of Ekaterinoslow, similar to the one just described, had observed the penetration of the atmospheric precipitation, the wetting and drying of the subsoil in various seasons and under various conditions, he came to the conclusion that, on the smooth uplands and on gentle slopes where the ground water lies deep beneath the surface, no leaching of the deep subsoil takes place through the percolation of rainwater from above. At a depth of 6 to 12 feet there is a stratum whose content of moisture remains more or less uniform throughout the year and this is always less than the water holding capacity of the material. This stratum he designates as a dead stratum. It constitutes a lower limit to the downward penetration of solutions, produced by the operation of the processes of soil building going on above, especially the compounds of difficult solubility such as gypsum and lime carbonate and also of those compounds that pass into an insoluble form. To this type belong the solutions of crenic acid which become reduced because of imperfect access to atmospheric air and becomes transformed into less soluble humic acids or salts. Consequently the mineral substances and a part of the organic substances remain behind in this layer through which the water does not penetrate. They precipitate and form accumulations visible to the unaided eye.

Wyssotzki designated all these organic and inorganic accumulations as Illuvium. The existence of the illuvial Tschernosem horizon was later questioned by Botsch. He maintained that the illuvium of Wyssotzki was nothing more than buried soil, changed by the soil forming processes now in operation.

In closing the discussion of the morphology of the Tschernosem we will call attention to the characteristic features of the Transcaucasian Tschernosem. In the first place the relief of the Tschernosem region in the vicinity of the Goktscha lake is not at all like the wide smooth plains of the Russian Tschernosem region. The surface is more rolling with here and there abrupt bare basaltic hills. The soil is derived from basalt also. The general character of the flora is like that of the Tschernosem steppes of Saratow. A surprising thing is the great abundance of Feather grass in places, especially in the vicinity of the village of

Elenowka. The Tschernosem lies here at an elevation of about 6000 feet. On level or smooth areas the soil has the following structure: The surface humus horizon is not different from that of the typical Russian Tschernosem. Immediately beneath it however there is a continuous white horizon with a high lime carbonate content, containing magnesium carbonates also. The deeper horizons appear to be cemented to the upper surface of the parent rock. In the profile a very prominent white streak lies between two black ones. On the slopes the morphology is somewhat different. Under the humus horizons there is a brown loamy material rich in carbonates. At a greater depth lies the Lava which here and there is replaced by volcanic glass.

These facts concerning the parent rock of the Tschernosem warrant the conclusion that among the representatives of this soil type varieties may occur which differ to an important extent in their mechanical composition, such as heavy loam, sand loam, imperfectly developed varieties, and others. That no true sand variety exists was predicted by Rupprecht[1] since air and water pass through sand very readily and promote the rapid decomposition of the organic matter. No considerable accumulation of humus can take place therefore. Where broad stretches of sand occur on the steppes they are usually covered with trees and Podsolic soils are usually developed. Anyone who crosses the Tschernosem zone of European Russia from Moscow to Saratow by way of Riasan, Koslow and Tambow will be easily convinced of this relationship. The Tschernosem-like loams and loamy sands are usually described in Russian literature as the end members in the series of light textured loose Tschernosem soils. They occur in Saratow. The predominance in the Russian steppes, of fine textured Tschernosem varieties over the coarse textured varieties is explained by the predominance of fine-grained varieties of parent rocks, such as loess and loessial loam. The following table giving the mechanical composition of the surface or humus horizon of Tschernosem from several places illustrates the predominant fineness of the texture of the soils of this type.

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[1] Rupprecht. Geo-botanical Investigation of the Tschernosem. Supplement to the X Report of the Imperial Academy of Science, 1866 (Russian)

Locality	Coarse: larger than 2 mm	Sand: 2-1 mm	Sand: 1 to 0.5 mm	Sandy Silt: 0.5 to 0.25 mm	Sandy Silt: 0.25 to 0.01 mm	Fine silt and clay less than 0.01 mm
Klutschischtschi, Nishni-Novgorod	0.295	-	0.079	0.044	47.071	58.323
Runowschtschina Poltawa	-	0.01	0.16	0.69	43.59	42.15
Kamennaja steppe, Woronesh	-	-	-	-	66.21	33.19
" " "	-	-	-	0.2	68.17	31.07
Weliko-Anadol, Ekaterinoslaw	-	-	-	-	67.40	30.00
Golotowschtschina, Poltawa	-	-	-	0.4	61.69	25.01
Enki, Poltawa	-	-	-	0.67	77.13	12.4
Siberian Tschernosem						
Sorotschia-Steppe, Tobolsk	-	0.2	0.99	1.62	30.59	66.60
Samiralowo	-	-	0.18	0.37	29.23	77.21

The loamy varieties of the Tschernosem are characterized by large water holding capacity and small capilarity. The 1st mentioned characteristic is a feature of the virgin soil, not yet brought into cultivation and still marked by a well developed granular structure. On cultivation the structure disappears, the upper horizons become floury in structure, its capillary capacity increases and its penetrability to water becomes considerably lessened.

Ismailski[1] made a study through a period of six years, of the distribution of moisture in the Tschernosem loam of Poltawa to a depth of about 7 feet. In addition to this he made a great number of determinations of moisture content in the same soil and its parent rock, from the surface to ground water level. On summing up his results he stated that during the six year period the average annual moisture content had varied considerably. These variations were not influenced by the amount of the average annual precipitation but were determined mainly by its character and by the season

[1] Ismailski. Bodenfeuchtigkeit und Grundwasser, Poltawa 1894

in which the greatest amount of it fell. The Spring and Autumn precipitation were of greatest importance while the summer rainfall exercised but a slight influence. The soil is dryest therefore at the end of summer, and the beginning of autumn. The following table shows in tabular form Ismailski's results:

	September October November of the previous year		Dec. of the previous yr. Jan., Feb. of the following year		March April May		June July August		Total rainfall from September to September	Mean soil moisture for this period	Soil Moisture in Cubic meters per Desjatine[1] to a depth of 215 cm	
	Rainfall in millimeters	Mean soil Moisture	Rainfall in millimeters	Mean soil Moisture	Rainfall in millimeters	Mean soil Moisture	Rainfall in millimeters	Mean soil Moisture			Spring	Autumn
1887	200.00	-	74.5	17.58	139.3	17.04	113.2	15.43	525.0	16.68	6673.8	4909.8
1888	262.8	16.61	114.3	20.19	78.5	18.92	208.1	17.33	663.7	18.24	7358.8	5855.5
1889	96.7	16.20	55.7	17.99	138.3	16.90	225.3	14.44	516.0	16.38	6291.6	5761.4
1890	111.0	16.49	28.8	16.12	95.4	15.49	185.7	13.53	420.9	15.41	5987.8	4184.4
1891	158.2	12.07	24.0	14.07	176.5	14.51	92.0	12.68	450.7	13.42	5301.8	3498.6
1892	53.3	10.81	99.6	13.08	82.4	13.45	180.7	13.46	416.0	12.69	4732.4	4202.2
Total	882	-	396.9	-	710.4	-	1005.0	-	-	-	-	-
Mean	147	14.43	66.1	16.50	110.8	16.05	167.6	14.48	-	15.36	-	-

1 A Desjatine is equivalent to about 2.7 acres.

The following table shows the range in moisture content in four horizons:-

	0 to 17.5 cm			52.5 to 70.4 cm			123.2 to 140.8 cm			204.6 to 211.2 cm		
	Max.	Min.	Difference	Max.	Min.	Difference	Max.	Min.	Difference	Max.	Min.	Difference
1887	26.92	10.27	16.65	20.72	12.74	7.98	18.58	14.85	3.73	17.78	13.81	3.97
1888	30.73	10.09	20.64	21.37	16.39	4.98	19.13	16.19	2.94	18.48	14.37	4.11
1889	26.09	7.58	18.51	18.83	12.31	6.52	18.01	15.11	2.90	16.91	14.01	2.90
1890	26.64	5.77	20.87	16.13	10.76	5.34	15.93	10.83	5.10	16.74	13.08	3.66
1891	29.02	8.89	21.13	18.15	9.52	8.63	14.19	10.03	4.16	14.29	11.89	2.40
1892	22.96	6.92	16.04	15.45	10.86	4.59	13.17	11.34	2.37	14.46	11.79	2.47
Mean			18.99			6.34			3.54			3.25
Max. and Min.	30.73	5.77	24.96	21.37	9.52	11.85	19.13	10.03	9.10	18.48	11.89	6.69

These figures show that the greatest variation of moisture content takes place in the upper soil horizons. The deeper the horizon the smaller is the variation in moisture content. Ismailski carried out a series of observations on the distribution of moisture in the whole Tschernosem mass and in the mass of underground parent rock, utilizing wells for the purposes.

In the following table wells I, II, III and IV are on a watershed in the steppe, well V lies on the same watershed in a depression. In wells I, II and III the ground water level lay in marl and the water was brackish. The marl underlies loess and is itself underlaid by vari-colored clay. In well IV a brown loess-like layer occurs at a depth of 9.23 to 9.94 meters.

Moisture in percent by Weight of the Soil

Depth in cm	I Djatsch-kowo 1888	II Dowbi-Schiewo 1889	III Djatsch-kowo 1890	IV Grigoren-kowo 1892	V Well in a basin at Djatsch-kowo 1893
71	9.48	18.25	10.12	12.59	21.11
142	11.23	12.96	12.46	12.86	21.34
213	11.68	10.34	13.17	12.91	19.35
284	11.95	16.22	14.02	13.79	22.52
355	11.00	16.13	14.99	15.57	22.65
426	11.13	13.15	12.91	17.38	20.69
497	12.53	18.33	12.49	18.44	18.51
568	15.45	10.57	14.31	17.36	16.78
639	16.21	10.66	15.00	14.28	18.31
710	16.40	12.19	15.53	18.08	18.43
781	16.39	14.16	17.09	19.21	21.34
852	15.30	18.26	17.06	20.89	19.26
923	14.47	19.86	16.85	22.71	19.35
994	17.96	20.53	16.11	22.94	19.85
1065	18.00	18.80	15.82	22.74	19.97
1136	18.04	19.16	16.86	21.63	20.43
1207	19.50	20.73	16.70	19.86	19.67
1278	20.74	20.08	15.39	20.87	20.29
1349	23.75	20.09	16.86	20.92	20.41
1420	-	22.37	20.68	20.28	21.09
1491	-	-	21.39	-	19.28
1562	-	-	22.08	-	-

The figures in this table give us the moisture content in weight, calculated in per cent of the moist soil. The water carrying parent rock (Brackish water marl) is shown to have a small water-holding capacity for when completely saturated it contains only 23 per cent.

We will now take up for discussion the chemical characteristics of the Tschernosem. The first characteristic to be noted in a general way is that these soils, even when cultivated are rich in humus. In the Tschernosem of European Russia the normal humus percentage may be stated approximately, as follows:

Northern Tschernosem	4 to 6%
Fat or Massive Tschernosem of northern latitudes	6 to 10%
Fat or Massive Tschernosem of southern latitudes	10 to 13% or more.
Ordinary Tschernosem	6 to 10%
Southern Tschernosem	4 to 6%

The following complete analyses of the various horizons of the Tschernosem at the village of Krutoje, parish of Balaschow, Saratow was reported by K. Schmidt:

	From 0 to 30 cm %	From 30 to 55 cm %	From 55 to 80 cm %	From 80 to 110 cm %	Deeper than 110 cm %
H_2O at 100° C	13.47	13.10	12.03	14.02	10.88
" " 150° C	1.35	1.38	1.03	1.47	0.90
Humus	14.85	11.37	8.69	6.16	3.54
SiO_2	44.35	55.83	57.87	54.32	48.20
Al_2O_3	15.79	14.84	15.75	14.61	14.65
Fe_2O_3	4.52	5.16	5.19	4.83	4.64
Mn_2O_3	0.07	0.08	0.09	0.10	0.09
CaO	1.94	2.05	1.54	5.82	10.00
MgO	1.55	1.48	1.92	1.76	1.47

Table (continued)

K_2O	2.27	2.37	2.33	2.27	2.03
Na_2O	0.71	0.58	0.84	0.88	0.86
CO_2	0.05	0.06	0.07	3.57	7.54
P_2O_5	0.22	0.18	0.16	0.16	0.15
SO_3	0.006	0.004	0.001	0.002	0.005
NaCl	0.007	0.004	0.003	0.003	0.006
N	0.607	0.417	0.272	0.180	0.076

In order to show what mineral substance the humus horizon has retained and what, when compared with the deepest, it has lost, the figures of the first and second columns, when calculated on a water, carbonate and humus free basis, give the following results assuming that there has been no loss of aluminum from any horizon[1]:-

	Percentage of each constituent retained	Percentage of each constituent lost.
K_2O	+	0.0
Na_2O	76.0	24.0
CaO	+	0.0
MgO	98.0	2.0
Al_2O_3	100.0	0.0
Fe_2O_3	90.0	10.0
Mn_2O_3	74.0	26.0
SiO_2	85.0	15.0

\+ Indicated that the horizon has been enriched.

The loss of constituents is shown to have been unimportant therefore. The parent rock, in the transformation to Tschernosem, has lost small amounts of sodium, iron, manganese, silica and magnesium. Similar results may be obtained by the recalculation of other analyses of Tschernosem soils. For example the following table gives the percentage composition of the Tschernosem of Tobolsk[2]:

1 The results are given in round numbers.
2 Kossowitsch. Report of the Agricultural Chem. Lab. of the Minister of Agriculture and The Imperial Domain, I Year, 1899 (Russian)

	Horizon A %	Horizon C %
H_2O at 100° C	4.57	3.37
Loss on ignition	10.74	5.90
Humus	7.58	2.40
SiO_2	64.28	61.10
Al_2O_3	13.61	12.69
Fe_2O_3	4.75	4.79
CaO	1.53	6.50
MgO	1.78	2.38
K_2O	1.55	1.53
Na_2O	1.28	1.89

When these results are calculated on a humus and carbonate free basis we get:

	Horizon A %	Horizon C %
SiO_2	71.74	71.33
Al_2O_3 Fe_2O_3	15.10) 5.30) 20.49	14.81) 5.59) 20.40
CaO	1.70	2.07
MgO	1.97	2.77
K_2O	1.97	1.78
Na_2O	1.79	2.20

To close this phase of the discussion the following analysis of East Siberian Tschernosem from the vicinity of Srietensk[1] is given:-

[1] Analyses made by Tomaschewski.

	Horizon A_1 %	Horizon A_2 %	Horizon C %
Loss on ignition	11.04	6.38	4.63
SiO_2	58.32	61.28	62.50
Al_2O_3	15.87	18.00	17.70
Fe_2O_3	6.09	5.62	6.50
CaO	3.42	2.80	2.91
MgO	2.05	2.29	2.21
K_2O	2.20	2.15	2.44
Na_2O	1.37	1.59	1.50

Calculating these results as above we get:

	Horizon A_1 %	Horizon A_2 %	Horizon C %
SiO_2	65.55	65.45	65.53
Al_2O_3 Fe_2O_3	17.84) 6.84)24.68	19.22) 6.00)25.22	18.56) 6.81)25.37
CaO	3.84	2.99	3.05
MgO	2.30	2.44	2.31
K_2O	2.47	2.29	2.45
Na_2O	1.54	1.69	1.57

The lime accumulations occasionally found in the A horizon are explained by the presence of considerable amounts of humic acid. The lime determination cannot be considered extremely exact since it is based on the determination of the CO_2 it being assumed that the latter is all combined with lime. In reality however part of it may be combined with the magnesia.

The following table gives us a comprehensive exhibition of the vertical distribution of humus and CO_2 in Russian Tschernosem[1]:

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[1] Dimo, Halbwüstenbodenbildung im Süden des Kreises Tsarizin, Saratow, 1907. S. 173.

Horizon	Depth in cm	Humus	Loss on ignition	Relative Humus Content	Solubility of the Humus	Relative Solubility of the Humus	CO_2
A	0 to 10	11.21	20.46	100.00	0.0470	1/240	0.096
	15 " 20	11.20	20.14	100.00	-	-	0.102
	20 " 25	7.897	16.81	70.5	0.0577	1/137	0.054
	30 " 35	7.298	15.41	65.0	-	-	0.065
	40 " 45	6.616	15.58	60.0	0.0573	1/115	0.076
B	50 " 55	4.916	13.35	43.8	-	-	0.087
	58 " 60	4.546	12.24	40.0	0.0397	1/115	0.072
	60 " 63	3.526	11.31	31.0	-	-	0.076
	65 " 69	2.896	11.42	26.00	0.0409	1/70	3.760
	75 " 80	2.520	11.09	22.5	0.0301	1/84	6.440
	85 " 90	1.801	9.607	16.0	-	-	7.59
C	95 " 100	1.585	8.893	14.0	-	-	7.11
	105 " 110	1.528	9.138	13.6	-	-	8.15
	115 " 120	1.323	8.988	12.0	-	-	8.55
	125 " 130	1.091	8.576	9.7	0.0219	1/50	8.84

From these results and from others of a similar kind scattered through the literature one sees that the maximum percentage of carbonates in the Tschernosem of the Russian steppes is about 16 to 17 per cent. The mountain Tscherrosems of Transcaucasia are much richer in carbonates, reaching a maximum of more than 20 per cent and often as much as 35 as shown in the following table. This is due to the richness in lime carbonate of the parent rock.[1]:

[1] Sacharow, "Pedologie" 1906, 1-4 p. 130-131.

Tschernosem of the Loris Steppes.

			CaCO
Sample 1.	Depth 70 - 88	cm.	31.81%
	" 88 - 105	"	30.05%
Sample 2.	" 52 - 70	"	24.70
	" 105 - 123	"	33.76

According to Sacharow[1] the average composition of the water extract of Tschernosem soils is as follows:

1	2	3	4	5	6	7	8	9	10	11
Horizon	Depth in cm	Color of extract	Residue on drying	Residue on ignition	Loss on ignition	Alkalinity as $2(HCO)_3$	CL	SO_3	SiO_2	CaO
A_1	10 to 25	golden yellow	0.0734	0.0366	0.0368	0.0196	0.0062	0.0030	0.0047	0.0160
A_2	30 " 80	Colorless	0.0640	0.0288	0.0362	0.0241	0.0061	0.0017	0.0039	0.0144
C	90 " 150	"	0.0644	0.0386	0.0258	0.0388	00.0039	0.0024	0.0031	0.0146

The percentage relationship of the figures in columns 5, 6 and 7 in the preceding table, to the total residue on drying and the same relationship of those in columns 8, 9, 10 and 11 to the total mineral matter present is shown in the following table:-

1	2	3	5	6	7	5	8	9	10	11
	Residue of drying %					Residue on ignition %				
A_1	10 to 25	100	49.96	50.04	26.70	100	16.85	8.15	12.77	43.48
A_2	30 to 80	100	44.99	55.01	37.66	100	17.57	4.90	13.53	41.46
C_1	90 to 150	100	57.21	42.71	60.25	100	10.10	6.22	8.03	37.82

1 Sacharow, Russian Journal for Experimental Agriculture IV, 1906.

Not only the deeper horizons of the Tschernosem but the surface as well react alkaline. This is due, according to Sacharow, to the presence of bicarbonate of lime. The amount of easily soluble organic and mineral substances does not vary widely. Of the soluble bases lime is the most important.

Another group of soils developed under moderate moisture conditions, in addition to the true Tschernosems, is included with the latter. These are the Tschernosem-like soils occurring in low areas and belts between and among areas of Chestnut Colored soils. Their profile is typically about as follows[1]:

Ao Peaty mass 1.5 to 2cm. thick.

A_1 Brown horizon, full of roots, with no well defined structure, 7.5 to 8 cm. thick.

A_2 Lumpy and compact with not well defined fine granular structure. Color in lower part spotted or mottled in Coarse nut cloddy structure. Thickness, 15 cm.

B Compact, breaks into small clods. In its upper part very mottled. In depth the light colored spots form broad massive tongues and irregular bodies as much as 27 cm. thick.

At a depth of 47 cm. the light colored spots between the dark colored tongues effervesce in acid.

C Loess-like clay. Contains neither chlorine nor sulphur dioxide to a depth of 150 cm.

In these soils the humus content seems to be determined partly by the latitude and partly by the depth of the depression in which the soils lie. In Saratow the percentage of humus is 7 to 7.5[2], in Turgai region[3] 4.6. The following table gives the data on the distribution of CO_2 in the two samples from these two regions[4]:

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1 Dimo, l. c.p. 71.

2 Dimo, l. c.p. 136-137

3 Lewtschenko, Arb. der Bodenexpedition für Enforschung der Kolonisations-Regionen des asiatischen Ruszland. 1908, Lief. 1.

4 Dimo, Halbwüstenbodenbildungen im Suden des Kreises Tsarizin Saratow. 1907, S. 173.

Soil No. III. Depth in cm	CO_2	Soil No. VI. Depth in cm	CO_2
5 to 10	0.030	5 to 10	0.063
25 " 28	0.026	25 " 28	0.048
30 " 45	-	40 " 45	0.097
-	-	50 " 55	3.186
45 " 50	0.037	60 " 65	4.375
70 " 75	4.089	75 " 80	5.890
80 " 85	5.371	85 " 90	7.136
90 " 95	6.176	100 " 105	6.230
105 " 110	-	105 " 110	5.430
125 " 130	4.202	125 " 130	4.321
150	2.890	150	3.165

A water extract of the dark colored soil from the Turgai region gave the following:

Horizon	Depth in cm	Residue on Drying	Residue on Ignition	Mineral matter	SiO_2	SO_3	CaO	Alkalinity as $2(HCO_3)$	CL	Color
A_1	0 to 19	0.0632	0.0462	0.0220	0.0003	0.0033	-	0.0141	-	Golden Yellow
A_2	19 to 50	0.0471	0.0266	0.0204	0.0007	0.0026	-	0.0145	0.0016	-
C	50 to 80	0.0710	0.0212	0.0487	-	0.0042	-	0.0516	0.0018	Pale Golden Yellow

Literature

The following references, in addition to those already cited, are given.

1. Abich, Bull. Acad. Petersb. 1854. XIII.

2. Blasius, Reise im europ. Russland in den Jahren 1840 to 1841, Braunschweig 1844.

3. Ehrenberg, Monatsberichte der Berlin. Acad. 1850.

4. Giedwillo, Bull. de la Soc. de Natur. de Moscou, 1851.

5. Grossul-Tolstoj, Report of the Agricultural Society of South Russia, 1857 (Russian).

6. Korolew, Report of the West Siberian branch of the Royal Geographic Society, Vol. XXIV (Russian).

7. Oldham, A manual of the Geology of India.

8. Ototżki, Literatur der russischen Bodenkunde, St. Petersburg, 1898.

9. Slowzow, Bericht der westsibir. Abt. der Kais. russ. Geograph. Ges., Bd XXI, 1897.

10. Ssinelnikow, Bericht des landwirtschaft. Institutes zu Moskau, 1900 Lief 4.

11. Sibirzeff, Der Tschernosem in verschiedener Landern. Oeffentlicher Vortrag. 1898.

12. Tanfiliew, Baraba und Kulundinische Steppe in der Altaj Region 1902.

13. Tichonowitsch, General Geography, 1902. Parts II-III (Russian).

SOILS DEVELOPED UNDER CONDITIONS OF INSUFFICIENT MOISTURE

The soils of this group cover large areas in semi-arid and arid regions. The zone of arid steppes of European and Asiatic Russia lies adjacent and parallel to the Tschernosem zone, there being a gradual change southward from the latter to the desert steppes. The grayish shade in the color of the southern Tschernosem shows the beginning of a change, for the soils of the desert steppes, whatever color they have, are always marked by the presence of a gray shade. These soils may be separated into three subgroups on the basis of color and humus content, as follows: (1) The Chestnut Colored soils. (2) The Brown Desert soils and (3) The Gray Desert soils. In subtropical latitudes red soils take the place of the first group, but should not be mistaken for Laterites or Terra Rossas since they differ greatly from them.

The Chestnut Colored soils lie farthest north of any of the semi-arid soils in Russia. They lie immediately adjacent to the Tschernosem zone and project into the latter in the form of tongues, along belts of low land. They cover, in the Volga region, a large area and extend thence eastward in a broad belt and westward in a narrow one. From the region of the Cossacks of the Don and the Crimea this belt stretches through the southern part of Bessarabia, Orenburg in the region of Uralsk, Turgai, Akmolinsk and Semipalatinsk. On reaching the Altai mountains the zone is replaced by a Tschernosem belt because of the influence of the mountains. True Chestnut Colored soils exist only in the valleys of the southern part of the mountains[1] but these small areas unite the West Siberian zone of these soils with the East Siberian zone. These soils are found in Eastern Siberia in the southern part of Jenisseisk, in the Minussinsk region but they are absent entirely from Irkutsk because of its elevation and mountainous character. They appear again in the southern part of Transbaikalia and extend thence in an unbroken zone into Manchuria where the zone terminates, like the Tschernosem zone, against a coastal belt of podsolic soils.

In Western Europe Chestnut Colored soils occur in Roumainia[2], Hungary[3], and also in Spain where they seem to have developed under the influence of the law of vertical zonality.

These soils have not yet been described from North America, but they occur there without much doubt, bounding the Tschernosem on the west. There is the greatest probability that they occur in South America also.

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1 Smirnow. Arbeit der Bondenexped. für Erforschung der Kolonisations Regionen des Asiat. Ruszland. Bodenuntersuchungen von 1909, Lief I, 1910.

2 G. Murgoci, Comptes Rendus de la premiers conference agrogeologique. Budapesth 1909.

3 K. Glinka, "Pedologie", 1909.

In addition to their occurrence in desert plains they are known to occur in mountain regions; for example, in Turkestan[1] where they appear as one of a series of vertical soil belts, lying above the belt of gray desert soils but below that of the Tschernosem soils.

Through the results obtained by the soil expeditions of the Colonial Administration[2] the geography, morphology and chemistry of the Chestnut Colored soils of the arid provinces of Western Siberia and partly also of Eastern Siberia have become known. We shall make use of these results to bring out the essential characteristics of these soils.

One of the most important of their characteristics is the dark brown color of the humus horizon, a color similar to that of a ripe chestnut. The dark brown color is accompanied, however, with a well defined gray shade, similar to that of the southern Tschernosem soils.

The following description will bring out the morphological features of these soils:-

Horizon A_1. The upper 5 to 7 cm of this horizon is laminated. It has a lighter color than the lower and is relatively loose. Its lower part is compact and lacks the granular structure so characteristic of the southern Tschernosem. On crushing, or on being struck, a dry lump falls into grains of about gunpowder size. It constitutes only about a third of the total thickness of the soil.

Horizon A_2. Light colored, compact as with the lower part of A_1. Neither granular nor nut structure. The color decreases in strength downward and disappears in the form of spots and tongues. The thickness of this horizon reaches a maximum of 60 cm. if the isolated tongues and pockets of humus which project downward in considerable number is not counted.

Horizons A_1 and A_2 have, occasionally, well developed but covered vertical cracks 5 to 8 cm. apart. Because of this and of the compactness of the soil the parts of the two horizons may be taken out as prismatic blocks. Effervescence in acid takes place in Chestnut Colored soils either in the lower part of the A_1 horizon or in the surface. The latter is true if the parent rock has a high percentage of carbonates. Chestnut Colored soils that effervesce on the surface are designated as carbonate soils. In the lower horizons gypsum and lime carbonate accumulations occur in the form of spots.

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1 K. Glinka, On the Classification of the Soils of Turkestan. "Pedologie", 1909, No. 4.
Neustrujew. Work of the Soil Investigation Expeditions to the Regions to be Colonized in Asiatic Russia. Soil Investigations, Part VII, 1908 (Russian)
Bessonow, Same, Part VI; and Prassolow, Same, Part V. (Russian)

2 Tumin, Same, 1908, Part 10. (Russian).

The Chestnut Colored soils, like the Tschernosems and Podsols, can be subdivided according to their mechanical composition into loam, sandy loam, clayey sand and other individuals. Sandy Chestnut Colored soils differ from the argillaceous and loamy members of the group in their light brown rather than dark brown color and often in the absence of the carbonate horizons. The mechanical composition of the several horizons of the loamy Chestnut Colored soils are very much alike as the following table will show[1]:

Depth	Sand			Sandy Silt				Fine silt and clay less than		Relation o
in cm	Coarse 3 to 1 mm	Mean 1 to 0.5 mm	Fine 0.5 to 0.25 mm	0.25 to 0.05 mm	0.05 to 0.01 mm	0.01 to 0.005 mm	0.005 to 0.0015 mm	0.0015 mm in diam.	Total	clay to sand
0 to 5	1.767	0.930	3.006	9.530	6.728	44.706	9.796	19.849	96.355	1:0.30
5 " 25	2.242	0.840	3.781	13.892	6.920	34.288	12.830	19.210	94.003	1:0.42
25 " 55	2.198	0.955	3.723	13.644	8.958	36.214	16.903	14.302	96.897	1:0.45
55 " 72	2.305	1.016	2.714	12.164	8.466	38.799	21.607	8.477	95.548	1:0.38
72 "100	1.750	0.822	2.794	12.173	8.779	37.013	24.407	7.607	95.345	1:0.38

The percentage of the finest material decreases with depth but that of silt increases. If these two groups of fine material be united into one, the difference between the various horizons in their content will be less than the usual error in analysis. The higher percentage of the finest material in the surface layer shows the influence of weathering processes. The translocation of fine grained material into the lower horizons does not seem to take place in these soils according to these results. No transfer of material chemically seems to take place according to the results of analyses shown in the following table[2].

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[1] Skalow, Arb. der Bodenexpedit. zur Erforschung des zu Kolonizierenden Teilen Asiat. Ruszland. Bodenerforschungen, 1909, Lief 2, 1910.

[2] Stassiewitsch, Arb. der Bodenexpd. usw. Bodenerforschungen 1909, Lief. 3, 1911.

Depth in cm	CO_2	Water at 100°C	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Total
0.5 to 4	-	2.89	8.25	62.78	15.01	5.09	2.45	2.14	1.72	2.18	0.150	99.992
5 to 12	-	2.49	6.14	64.07	15.41	6.15	2.72	1.40	1.64	2.12	0.125	99.815
11 to 17	1.13	1.80	4.26	65.20	15.46	5.60	2.97	1.98	1.73	2.32	0.140	99.748
C 57 to 63	0.63	1.77	3.42	65.69	15.63	6.42	3.42	1.22	1.43	2.13	0.137	99.535

Calculating these results on the basis of mineral matter alone, we get:

Depth in cm	CO_2	Water at 100°C	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	Total
0.5 to 4	-	-	-	68.42	16.36	5.55	2.67	2.33	1.87	2.38	0.163	-
5 to 12	-	-	-	68.26	16.42	6.55	2.90	1.49	1.75	2.26	0.133	-
11 to 17	-	-	-	69.98	16.59	6.01	1.64	2.13	1.86	2.49	0.150	-
C 57 to 63	-	-	-	69.04	16.43	6.75	2.75	1.28	1.50	2.24	0.144	-

The content of humus decreases gradually with depth as is shown in the following table:

Depth in Cm	Humus %	Hygroscopic Water %	Loss on Ignition %
0 to 2	4.02	3.12	5.51
3 " 14	3.24	3.42	4.50
11 " 18	2.75	2.63	4.33
19 " 28	2.12	2.31	4.08
35 " 45	0.94	1.74	2.48

[1] Stassiewitsch, l. c.

The maximum humus content in the Chestnut Colored soils is about 5 per cent. The greater part of these soils in Eastern and Western Siberia contain no more than 3 to 4.5%. The Hungarian representatives contain the same amounts, those from the vicinity of Szabadka for example containing only 3.11% while those from Szeged contain 4.6%.

The humus horizons of the Chestnut Colored soils are low in their content of water-soluble substances. In the lower horizons however, considerable quantities of salts are sometimes encountered. The following tables give some analytical data for the soils of Jenisseisk. (See Page 147)

The Brown Earth was raised by Dokutschajeff to the position of a distinct and independent group of soils. He studied its development in the country adjacent to the Caspian Sea. Since he differentiated the soils of European Russia mainly according to color and the content of humus, he did not therefore give sufficient attention to the morphology of the Brown Earth. Since the structure of the Brown Earth and the Chestnut Colored soils is identical it is a debatable question whether these soils, solely on the basis of a difference in color, should be separated into two groups.

In the investigation of these two groups the investigator encounters an important phenomenon. The soil zone lying south of the Chestnut Colored zone in Asiatic Russia occurring also in certain regions of European Russia contains soils which have not only a lighter fundamental color than the Chestnut Colored soils but also at certain depths are more compact: That is to say, in horizon A the compaction, usually developed in B only, begins to develop. Such soils were grouped with the Solonetz-like soils, some authors[1] designating them as such rather than as Brown Earth soils. Since soils with a compact horizon B as well as soils without such compaction are found among the Brown Earth soils as well as among the Chestnut Colored soils[2], such a grouping seems advisable. To the Brown Earth soils without compaction in horizon B are to be grouped[3] the soils south of Lake Balchasch and the light brown loams of the northern part of the Semiretsche region beyond the Balchasch basin and the brown loams of certain areas of Samara[4]. Since the color shade of the soil, where it has not been determined by the color of the parent rock, is no accidental matter, but constitutes instead an important characteristic of the soils

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1 G. Tumin, Work of the Soil Expedition, etc. 1908 Part 10, 1910.

2 Neustrujew, Pedology, 1910, No. 2.

3 K. Glinka and Associates, Occasional Communications of the organization and progress of the investigation of the soils of Asiatic Russia in 1909. St. Petersburg, 1910, p. 2 (Russian).

4 Neustrujew; ibid.

The Smooth Steppes of Askyr

Depth in cm.	Color	Alkalinity as 2(HCO_3)	Residue on drying	Residue on ignition	Mineral matter	CL	SO_3	K_2O	Na_2O
0 to 3	Yellow	0.0192	0.0544	0.0316	0.0228	tr	-	-	-
3 to 9	Yellowish	0.0216	0.0548	0.0316	0.0232	tr	tr	-	-
11 to 18	Pale Yellow	0.0192	0.0580	0.0340	0.0240	tr	tr	-	-
19 to 28	Almost Colorless	0.0403	0.0732	0.0434	0.0298	0.0002	0.0058	-	-
35 to 45	Colorless	0.0537	0.0744	0.0242	0.0502	0.0004	0.0044		

The Hilly Steppes of Abakan

Depth in cm.	Color	Alkalinity as 2(HCO_3)	Residue on drying	Residue on ignition	Mineral matter	CL	SO_3	K_2O	Na_2O
1 to 6	Bright Yellow	0.0228	0.0728	0.0488	0.0.240	0.0006	0.0040	-	-
8 to 14	Yellowish	0.0144	0.0502	0.0314	0.0188	tr	0.0016	-	-
23 to 29	Somewhat Yellowish	0.0384	0.0826[1]	0.0433	0.0393	0.0024	0.0093	0.0012	0.0015
34 to 39	Almost Colorless	0.0456	0.0656[2]	0.0356	0.0500	0.0010	-	-	-
71 to 78	Colorless	0.0672	0.01408[3]	0.0304	0.1104	0.0129	-	-	-

[1] Effervesces faintly in HCL
[2] " in HCL
[3] Fuses and effervesces in HCL

of the various zones, and[1] since it remains constant over stretches hundreds of miles in extent it can hardly be considered as having less value as a basis of classification than the structure, or the development of the compact horizon B. On that account in my opinion, the Brown Earth soils must be separated from the Chestnut Colored soils. I shall designate as Brown Soils those varieties which have no compaction in the B horizon. All brown soils with a well compacted B horizon will be discussed with the alkali and related soils. As stated above the Brown Earth soils differ from the Chestnut Colored soils in their lighter brown color but it must be remembered that the surface of all desert steppe soils is usually characterized by a gray shade. As a result of this lighter color, the humus horizons of these soils can be distinguished from the humus free horizons with more or less difficulty. The average thickness of the humus horizons lies between 40 and 50 cm. Tumin[2] described two profiles of the light brown loam of the Balchasch basin, in the semiretsche region as follows:

I. On the Ili in the lowest part of the steppe with Artemisia and Ceratocarpus.

Horizon A_1. From 1 to 5 cm, fine grained not laminated with no noticeable compaction. At 15 cm. faintly laminated and compacted. The thickness of the laminae amounts to about 1 mm. Their upper and lower surfaces are similarly colored. The transition to horizon B which takes place at about 15 cm. is gradual and difficult to determine exactly.

Horizon A_2: Unlaminated and faintly compacted. Lime carbonate spots are absent. Total thickness about 25 cm.

Horizon B. This horizon has a whiter color than horizon A_2. Important development of lime carbonate spots.

II. On higher land in this region (in the vicinity of the Anrak... Anrakajski Mountain) the soil profile is as follows:

Horizon A_1. From one to 2 or 3 cm., porous and laminated, often however cellular and unlaminated. At greater depth up to 8 cm. faintly laminated and at 19 cm. the lamination is absent entirely. It is faintly compacted and not granular. The thickness of the whole horizon amounts to 19 cm. The transition to A_2 is gradual.

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1 I had the opportunity some time ago to compare samples of Chestnut Colored soils from Roumania, Hungary, Turgai, Akmolinsk, Transbaikali and Manchuria. All samples had the same color to such an extent that one would think they came from the same spot.

2 Preliminary communications on the Organization and Results of the Investigation of the soils of Asiatic Russia in 1909. St. Petersburg, 1910, p. 72 (Russian).

Horizon A_2. Somewhat browner than the last, faintly compacted at 35 cm, not granular. At about 56 cm lime carbonate spots appear and the compaction increases. The whole horizon is 37 cm thick.

Horizon B. Light brown loam with a small amount of lime carbonate spots.

These soils effervesce in acid on the surface and belong therefore to the group of carbonate soils. Brown loams are known to exist however which do not effervesce on the surface.

The sandy loam and sandy varieties of the Brown soils are well developed in the lowland surrounding the Caspian Sea as well as in the steppe states in general and are known to occur also in the northern part of the Semiretschje region. In the latter the light brown loam forms the transition to the southern Gray Earth soils. In the Brown Loams the humus content ranges from 1 to 2 per cent and the percentage decreases gradually from the surface downward.

The following table shows the distribution and amount of humus, hygroscopic moisture, water of crystallization, loss on ignition and carbon dioxide in the Brown loams of the northern Semiretschje:[1]

Region		Depth in cm.	Humus %	Water at 100° C %	Combined water %	Loss on ignition %	CO_2 %
In the Tarbogataj north of Bachty		0 to 7	1.878	1.625	2.987	6.649	0.859
		10 " 26	1.210	1.528	2.536	7.335	2.061
	C	40 " 45	0.344	1.662	2.001	9.233	4.726
East of Alakul near Karaagatsch		0 to 8	1.750	1.275	2.729	6.156	0.401
		10 " 22	0.936	1.875	3.377	7.776	1.412
		45 " 50	0.690	2.991	3.065	8.710	1.964
	C	70 " 80	0.349	1.650	3.016	-	1.949
From the vicinity of Lake Tauke-Kul		0 to 6	2.04	1.06	0.41	4.89	1.41
		8 " 24	1.41	1.61	0.83	7.50	3.60
		26 " 40	0.495	2.29	1.52	12.85	8.04
	C	60 " 80	0.240	1.06	1.06	19.67	17.31
		90 " 95	0.207	0.87	0.80	9.30	7.42

[1] Prosslow. The work of the soil Expeditions for investigating the regions of Asiatic Russia that is to be Colonized. Expeditions of 1909, Part 4, St. Petersburg (Russian).

The water extract of Brown Loam soils shows that, like the Tschernosem and the Chestnut Colored soils, these soils have a low content of soluble salts. To show this the following table shows the result of an examination of the Brown Loam of Semiretschje:

Depth in cm.	Color of the extract	Residue on drying	Residue on ignition	Alkalinity as (HCO_3)	CL	SO_3	CaO	MgO
0 to 8	Faint Yellow	0.0565	0.0330	0.0343	0.0014	tr	Perceptible trace	tr
13 " 50	Colorless	0.0410	0.0276	0.0274	0.0007	-	"	"
C 65 " 75	"	0.0323	0.0241	0.0206	0.0017	-	tr	Faint trace

It is unfortunate that no complete analysis of the Brown Earth soils is in existence. It can be maintained however on apriori grounds that from such analyses as from those of the Chestnut Colored soils no noticeable translocation of the various compounds from the upper to the lower horizons could be detected.[1]

The Gray Earth soils (Fig.) were first studied in the Syr Darja region where they cover the plateau and valley slopes. They occupy positions that give facilities for good surface drainage[2].

As long as very little was known of the soils of Turkestan they were designated as aeolian loess soils or simply as loess soils. In this region the term loess was used to designate a parent rock[3] material which is widespread in its occurrence and which was supposed to be still in process of accumulation. The investigators believed therefore that the soil forming processes were going on in this region simultaneously with the purely mechanical processes of loess deposition. A full investigation of the soils of the region has shown us that the soil forming processes taking place on the plains in this region as in other regions runs in a normal course and that no noticeable mechanical process of sedimentation is taking place.

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1 Prassolow. The work of the Soil Expedition, etc. Soil Expedition 1909, Part 4. St. Petersburg (Russian)

2 Neustrujew. The work of the Soil Expedition, etc. Soil Investigation 1908, Part 7, 1910. Our description of the Gray Earth soils is taken from this work.

3 Sibirceff. The Science of Soils - Kossowitsch.

By whatever means the loess was accumulated, its formation is no longer going on and if occasional local dust transportation can be seen going on today it is nothing more than may be frequently seen in deserts and semi-arid regions where no loess exists. Although the Gray Earth soils of Turkestan overlie loess and loess-like material mainly, yet cases are known in which they have been formed on other kinds of parent rocks.

The structure of the Gray Earth soils is determined to a great extent by the work of earthworms, which occur here in association with a great number of burrowing insects and reptiles. The upper horizons are of a light grayish color, ranging from gray to grayish brown. The color changes within 10 to 20 cm to a brownish. In 30 to 50 cm it becomes gray because of the presence of a great many carbonate streaks, strips and spots; at still greater depth the color becomes variegated by the carbonate present and finally grades downward into the uniform grayish brown loess.

In the upper part these soils are faintly laminated and a distribution in lenses is noticeable. The soil is of medium friability and compactness because of the penetration by grass roots. At a depth of 5 to 10 cm the soil is loose. The deeper lying horizons are cellular and loose, due to the great number of worm passage ways. A shovel will penetrate it easily but as soon as the carbonate horizon has been reached the soil often becomes as hard as stone.

The structure of the carbonate horizon is lumpy or coarse nut-like. Below 30 cm and often not above 200 cm. the soil becomes again quite loose, a characteristic that is a feature of the loess. Beneath the carbonate horizons, gypsum crystals occur, usually at from 130 to 200 cm. The upper soil horizons are dry in summer, moisture occurring beneath the carbonate horizon and then only in the small amount characteristic of the loess.

Naturally the mechanical composition of the Gray Earth soils is determined by the character of the parent rock, so that the soils of this group that overlie loess differ from each other in accordance with the varying composition of the different kinds of loess. T Typical soils of the group contain a maximum of 40 percent of clay and fine silt. In mechanical composition the several horizons of these soils are very much alike as is shown in the following table:-

Locality	Depth in cm	larger than 3 mm	3 to 1 mm	1 to 0.5 mm	0.5 to 0.25 mm	0.25 to 0.05 mm	0.05 to 0.01 mm	less than 0.01 mm
North of Wrewskoe in Tschimkent district	0 to 7	-	-	0.06	0.04	19.15	33.04	47.71
	12 " 26	-	-	0.01	0.02	19.66	33.01	47.30
	50 " 60	-	-	0.06	0.02	14.77	35.47	49.68
	103 " 110	-	-	0.02	0.02	27.57	31.89	40.50
	172 " 180	-	-	-	0.01	17.32	40.85	41.82

The distribution of humus and carbonic acid is shown in the following table[1].

Locality	Depth in cm	CO_2	Humus	Water at 100° C	Combined water	Loss on ignition
Wrewskoe in Tschimkent	0 to 3	4.93	2.00	1.34	1.68	3.68
	13 " 26	6.72	0.45	1.62	1.68	2.04
	50 " 60	8.92	0.26	1.61	1.41	1.67
	103 " 110	10.74	0.22	1.31	1.33	1.56
	172 " 180	8.52	0.13	1.48	1.20	1.33
East of Arys Station Tschimkent district	0 to 7	5.10	1.61	1.32	1.02	2.63
	8 " 15	5.52	1.09	1.29	1.40	2.49
	15 " 22	6.20	0.38	1.38	1.62	2.00
	90 " 100	10.30	0.23	1.42	0.96	1.19
	137 " 145	9.32	0.21	1.45	1.4	1.62

[1] This analytical data is taken from the work of Neustrujew, cited above.

Only the upper 15 cm contain, as shown by these tables, more than 1% of humus. Below a few centimeters in depth the percentage sinks to a few tenths per cent. The boundary, in the Gray Earth soils, between humus and humus free horizons is not easily located. The distribution of carbonic acid points strongly to the carbonate content. In almost all samples studied carbonates are noticeable at depths varying from 50 to 150 cm. and the maximum is usually found between 100 and 120 cm. This latter is the characteristic carbonate horizon characteristic of the soils of the steppes and semi-arid regions and it is the product of soil building processes.

In the Gray Earths the carbonates line the underground habitations of worms and beetles forming a crust around them. The carbonate content is doubtless determined by the climate. Carbonates are not leached out because of the dryness of the climate. The upper soil horizons, compared with the parent loess, are poorer in carbonates, while the carbonate horizon is richer. A translocation or transfer of material has taken place therefore.

The water extract of the Gray Earths has the following characteristics:

Locality	Depth in cm	Residue on drying	Residue on ignition	Loss on ignition	Solubility of the humus	Color of the extract	Alkalinity as $NaHCO_3$
East of Arys Station	0 to 7	0.0566	0.0354	0.0212	1/76	Yellowish	0.0344
	8 " 15	0.0576	0.0465	0.0111	1/98	Colorless	0.0344
	15 " 20	0.0445	0.0364	0.0081	-	"	0.0344
	90 " 100	0.0324	0.0283	0.0041	1/55	"	0.0344
	137 " 145	0.0365	0.0314	0.0051	1/41	"	0.0365
North of Wrewskoe	0 to 7	0.0552	0.0281	0.0271	1/77	Yellowish	0.0355
	13 " 26	0.0345	0.0254	0.0091	1/50	Colorless	0.0344
	50 " 60	0.0351	0.0290	0.0061	1/43	"	0.0368
	103 " 110	0.0273	0.0188	0.0085	1/27	"	0.0307
	172 " 180	0.0386	0.0267	0.0119	1/11	"	0.0376

The content of chlorine, in the several horizons of the above samples ranged between 0.0010 and 0.0027 per cent. In the first sample the SO_3 is absent entirely, the second contains 0.0010 to 0.0046. These figures show that the Gray Earth soils, like other zonal semi-arid soils contain a very small percentage of soluble salts. The complete chemical analysis of the Gray Earth soils, shows that no transfer of oxide groups from one soil horizon to another has taken place.

In the following analysis of the sample from East of Arys Station, the potash and soda were not determined:

	Depth in cm.			
	0 to 7	8 to 15	90 to 100	137 to 145
Water at 100° C	1.34	1.31	1.44	1.47
Humus	1.61	1.08	0.23	0.21
Combined Water	1.02	1.41	0.95	1.41
CO_2	5.10	5.52	10.31	9.34
SiO_2	59.84	59.66	52.86	53.76
Al_2O_3	11.18	11.33	10.25	10.18
Fe_2O_3	5.19	5.35	4.89	5.30
CaO	7.24	7.66	13.06	12.11
MgO	3.08	2.82	3.01	2.82
P_2O_5	0.201	0.23	0.104	0.130
SO_3	0.553	0.160	0.223	0.059
Alkalies by Difference	4.98	4.84	4.11	4.68

An exact recalculation on a humus free and carbonate free basis is impossible in this case for it is certain that a part of the magnesia is combined with the carbonic acid, but the amount so combined is unknown. The carbonate free amounts are very much alike in all the horizons.

The Gray Earth soils are known to occur both in Turkestan and in Transcaucasia. Associated with them are varieties that constitute transitions to the calcareous crusts of the deserts. The kind of Gray Earth described first by Dokutschajeff[1] is one of these transition varieties. It was found in the vicinity of Erivan. These soils were identified in the vicinity of the city as well as in a belt 30 wersts long extending northwestward and eastward. According to Dokutschajeff there occurred everywhere on the surface of the Basalt and trachyte rocks white coatings either solid or floury in consistency 2.5 to 7.5 cm thick. The same soils occur on the southwestern side of the foot of Alages mountain extending from here into the Araks valley and rising again to the slope of Ararat. They are found also between Aralyk and Achury as well as in strips and islands in the Araks valley and on the slopes of the latter on the Kulp and Kagysmann side. The south shore of the Goktscha Lake as well as the Muganj and Karabach steppes are covered with these soils. In the smooth areas of the latter the Gray Earth soils have been developed on unconsolidated deposits and in that respect are similar to the Gray Earth soils of Turkestan. They are high in their content of soluble salts in the above mentioned steppes and grade into alkali soils.

The Gray Earth soils of Erivan, which I have had the opportunity of seeing on the way from Suchoj-Fontan to Erivan appear often as a thin soil covering overlying the basaltic parent rock to which it is attached as though it were cemented to it. In the upper part however they fall into a gray powder. The morphology of these soils could not be investigated at the time because the whole area regardless of the shallowness of the soils was under cultivation. It was noticed however that the loose mass effervesced on the surface.

The Gray Earth soils of Transcaucasia, developed on unconsolidated rocks, are quite porous in the surface and have a well developed laminated structure, a feature characteristic of the soils of desert steppes. The Eurasian zone of Gray Earth soils extends westward as far as Spain. They have been briefly described by Ramann[2] who did not describe their morphology however. He remarked that the soils in the region surrounding Madrid, developed on Pleistocene deposits, were almost white with a faint gray shade. According to my own observations in the Madrid region the soils of the gray semi-arid regions of Spain are very much like the soils of Transcaucasia in their morphology. Alkali varieties as well as varieties with no compaction in the B horizon were found in association with them also.

In closing the description of the soils of the semi-arid regions the Red Colored soils of the subtropics and certain areas of the warm temperate zones, all of which are but little known,

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1 Dokutschajeff called them White Earths, but in the form of powder they are more gray than white.
2 Ramann, "Pedologie", 1902, No. 1.

must be mentioned. Soil literature contains short references to red colored soils containing lime carbonate concretions, though nothing is said as to their morphology. We have in our collection in the Soil Institute at Nowo Alexandria a sample of such soil from the semi-arid region of Australia in which the structure of the upper horizon can be seen. It is as well laminated as are those semi-arid soils already described. It is evident that such a structure can be found only in rather fine grained and somewhat sticky soils.

The red soils of Spain, which I have seen in the vicinity of Salamanka, Valladolid and in the southern part of the Pyrenaean peninsula belong to this group[1]. Alkali varieties seem to exist also. The humus horizons can hardly be distinguished from the humus free, though the latter are rich in carbonates. The carbonates form, in places, a thick bed or stratum. In the railway cuts one can often see to what depth the carbonate streaks penetrate and the details of the interlacing net work which they form. Similar soils have been identified in Asia Minor, Palestine and apparently in Persia. The red colored sandy semi-arid soils of subtropical and warmer latitudes must be included in this group. For example, the whole desert of Central Arabia is covered with sandy red colored soils. Red sands are known to occur in the desert of Africa[2] and in central Australia[3]. The red color of these soils suggested to Walther the question as to whether it is a phenomenon of the same kind as that of the "protecting crust" formed on exposed surfaces of consolidated rocks of the desert. The coat of iron oxide soluble in hydrochloric acid which surrounds the individual grains of desert sand in central Arabia, on analysis by Phillips[4], amounted to .21%. In our opinion the red color in these soils, as in other cases already mentioned in this volume (Laterite, Red Soils of Semiarid regions) is due to the presence of Turgite, the formation of which is more easily explained here than in the Laterite region.

A complete analysis of red desert sand gives the following:-

SiO_2	98.53
Fe_2O_3	0.28
Al_2O_3	0.88
CaO, Mg and R_2O	traces

We will pass now to a consideration of the characteristic soil formations of the true deserts, the so-called Desert Crusts.

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1 See Ramann, l.c.
2 Wilkinson. Die Kalahari Wüste. Peterm. Mitteil, 1892, IV.
3 The sands of the Savannas of tropical latitudes are apparently like these soils. How the members of the group are to be differentiated is not yet known.
4 Phillips, Quarterly Journal, Geolog. Soc. London. 1882.

In regions with well developed desert characteristics, organic weathering becomes of very little importance on account of the very small amount of organic matter present. An energetic mechanical disintegration of the rocks takes place producing a fine grained mass of earthy material which however does not constitute a soil. The strong winds that predominate in desert regions blow the greater part of this fine grained material out of the desert into its border land, leaving only the coarser material behind. This consists of sand, gravel, stone fragments and in places bare rock ledges. For this reason soils in the form of unconsolidated deposits are never found in true deserts like they are found in other climatic regions. Walther says[1] the desert is rich in geographic paradoxes. "There are clouds without rain, springs without brooks, rivers without mouths, lakes without outlet, dry valleys and deltas, waterless basins lower than the level of the sea, energetic weathering without a coating of weathered products, and plants without leaves. All these are characteristic earmarks of the desert". We cannot entirely agree with Walther in his characterization because of his omission of the Desert Crust. It is undoubtedly present, perhaps, as Walther might insist, due to forces not recognized by Walther as characteristically those of the desert.

Desert soils like other desert phenomena are unique. Although very little moisture is present yet there is a strong mechanical weathering. The salts which under other climatic conditions disappear from the soil or are carried to deeper horizons accumulate in deserts and take part in chemical and mechanical weathering.

Mechanical weathering is effected by salts through crystallization in small crevices in the rocks and the production thereby of strains tending to split them in exactly the same way as freezing or crystallizing water. The salts of the deserts act on the rocks when they are brought to the surface through the capillary rise of water holding them in solution. This process is slow so that there is plenty of time for an energetic chemical reaction between such solutions and the rocks containing them. At the same time there is a concentration of the solution and a crystallization of salts. By this means it can easily be seen that a chemical and mechanical weathering of the rocks from the inside may take place and reach an advanced stage while the surface remains hard, intact and but slightly changed. Limestones in deserts are often hard, at the surface giving out a clear ring when struck with the hammer yet under this surface layer the stone is hollow and on the bottom of the hollow lies a loose fine grained mass of weathered product. All surface stones of the desert are rich in salts and according to Walther all desert soils carry soluble salts. This is no reason however for placing all desert soils in the group of Alkali soils. That the surface stones of the desert may be very rich in salts is shown by the following facts observed by Frass[2].

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1 Joh. Walther. Des Gesettz der Wüstenbildung, 1900.

2 O. Frass, Geologisches aus dem Orient, 1867.

A fragment of marl from Mokkatam was immersed for a whole day in fresh water, was then washed three to four times but after each washing became again coated with a layer of sodium bicarbonate.

Among desert crusts three types are known at present: The Lime Crust, Gypsum Crust and the Protective Crust. The first has long been known and has attracted much attention. The others have been discovered to be characteristic of many deserts and have been studied only within recent years. The characteristics and significance of the Lime and Gypsum crusts have been made known to us through the studies of Johannes Walther, Blanckenhorn[1] and American investigators.

We shall concern ourselves first with the work of Blanckenhorn in North Africa. This investigator divided the deserts of Egypt, on the basis of the character of the surface material, into three zones differing from each other in various climatic features mainly in temperature and precipitation. A glance at the rainfall chart shows that Egypt lies partly in one climatic zone and partly in another. The Nile delta and the Lybian desert including Syria, Tunis, Algeria and Morocco lie within the zone of winter rain that stretches over the Mediterranean region. In all this region the surface formations are uniform. The easily soluble salts, such as sodium bicarbonate and gypsum are as fully leached out of these soils as they are from the soils of the temperate zone of Europe. Since the rate of evaporation is not less than in the central part of the desert, solutions of the salts that dissolve with difficulty, the easily soluble salts being absent, rise to the surface, are there precipitated by evaporation and form hard crusts. In this way crusts of bright red, brown, gray and white colors composed of carbonate of lime, silicates, oxide of iron, traces of sodium chloride and water are formed. Incorporated in this material are grains of quartz, fragments of silicious rocks, shells of Helix and other terrestrial molluscs.

The lime crust was found by Blanckenhorn in the Atlas Mountains also. It covers also the rolling surface of the Tunisian plain with a layer a meter thick in many places. This is especially true of the more elevated and dryer places where evaporation is strongest. In the plateau of Algeria and in the interior of Morocco, the lime crust occurs in a very large area, is about 50 cm thick and is wholly independent of the relief and the parent rock. Where it covers a material that is dry to considerable depths, as for example between Bogar and Djelpha, the natives construct underground dwellings very easily by breaking through the crust at one spot and excavating the soft material below it. In the northern part of Syria on the border of the north Syrian desert, between Homs, Selemije and Aleppo,

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1 Blanckenhorn, Petermanns Mitteilungen Erganzungsheft 90, 1888; Zur Kenntnis der Süszwasserablagerungen und Mollusken Syriens. Palaeontographica XLIV, Zeitschr. der deutsch. Geol. Gesellschaft 1902, 53, H, 3.

Blanckenhorn found the same soil formation, about 50 cm. thick. In Palestine O. Frass had described at an earlier period the same kind of crust. In the vicinity of Jerusalem it is called "Nari". According to the latest information[1] on the subject the "Nari" or surface breccia ranges in thickness up to 2 meters.

Blanckenhorn identified it on the road from Meks to Monghara. It covered hills made up of marine Quaternary deposits like a cloak three quarters of a meter thick. Its color is gray to reddish and the percentage of silica ranges from 1 to 9. Southeast of Bir Hamam, this formation, although irregularly distributed, has been identified in a belt 70 kilometers wide in the northern part of the Lybian desert. It appears somewhat different here however, being characterized by a dirty flesh color and occurs on the surface of rocks, especially the Pleistocene limestones, where the surface of the latter is made by this means much harder than the interior. A similar lime crust occurs also in North America (Texas, New Mexico) where it is widely distributed in places and goes by the name of "hardpan"[2]. In his description of the desert region of this country, Johannes Walther says that the crystalline and paleozoic rocks are coated with a white lime coating which is hard enough to hold pebbles fast. Those parts of North America in which the lime crust has been identified have the same rainfall as the southern Atlas Mountains, Palestine and the interior of Syria.

In general it is well known that the lime crust is rather widely distributed and is a characteristic phenomenon of deserts and semi-arid regions. A thin crust surrounding the separate grains of sand in deserts and semi-arid wastes belongs to the same kind of thing. It is found in the sands of Hungary where it occurs in the zone of Chestnut Colored soils. Such crusts are widely distributed among the sands of Turkestan also. Certain Gray Earth materials of Transcaucasia already described are similar to these crusted sands. In chemical composition they seem to range about as follows, based on analyses of the soils of Syria:

Combined silica	3.2	to	7.2%
Al_2O_3	1	"	2.1%
Fe_2O_3	0.8	"	1.2%
$CaCO_3$	88.4	"	85.2%
NaCL	1.3	"	10.0%
H_2O	4.2	"	2.4%

1 Blanckenhorn, Zeitschrift der Deutsch. Palast. Verein V, 1905, 28.

2 United States Department of Agriculture. Report No. 64. Field Operations of the Division of Soils, 1899, Washington, 1900.

In poorly drained parts of Egypt where the rainfall is low, the lime crust is replaced by one of gypsum, while breccias with gypsum cement are of common occurrence. The quartz grains and stone piles and fragments lying on the surface are cemented into an open coarsely porous mass by a cement composed of gypsum and lime carbonate or of gypsum alone. This crust becomes covered by the wind, with a deposit of silt and sand. The occurrence of gypsum where found below the surface however may be explained through the crystallization of solutions containing calcium sulplate before they reach the surface. Dokutschajeff referred the gypsum of Repetek in Transcaucasia to processes of crystallization which take place most easily in a medium of lessened capillarity. In Egypt the gypsum is obtained for commercial purposes from such crusts but after a few years it has formed again in the same place. The gypsum crusts of the northern African deserts were investigated before Blanckenhorn's time by Piccard[1] from whose work we take the following analytical data:

Sand and clay	62.9 %
$CaCO_3$	0.8 %
$CaSO_4$	27.5 %
KCL + NaCl	0.16%
H_2O and organic matter	8.64%

According to descriptions by Streich[2] gypsum crusts occur in the deserts of Central Australia.

In the desert regions of North America gypsum crusts are found and have been described from New Mexico[3]. They cover wide irregularly formed surfaces, one north of Black river, the other south of it. It is locally known as "Jeso". Means and Gardner say "The gypsum is granular. In dry condition the soil is dense and hard, but on wetting it absorbs moisture like sugar and becomes soft and penetrable". The mechanical composition of the New Mexico gypsum soils is shown in the following table:

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1 Piccard, Vierteljahresschrift der Naturforsch. Gesellschaft zu Zurich, 10, 67.

2 V. Streich. Scientific Results of the Elder Exploring Expedition. Trans. Royal Soc. South Australia, 16.

3 U. S. Dept. of Agriculture. Soils Survey of the Pecos Valley, N.M. Field Operations of the Division of Soils, 1899, Washington 1900.

	1	2
2 to 1 mm gravel	-	-
1 to 0.5 mm coarse sand	trace	-
0.5 to 0.25 mm medium sand	3.26	2.58
0.25 to 0.1 mm fine sand	9.42	14.25
0.1 to 0.05 mm very fine sand	38.47	37.13
0.05 to 0.01 mm silt	12.67	13.95
0.01 to 0.005 mm fine silt	10.87	8.88
0.005 to 0.001 mm clay	19.70	15.46
In 1.5 liters of water used in the mechanical analyses there were dissolved salts	1.90	2.34
Loss on drying at 110 C	3.03	2.80
" " ignition	3.41	3.27

In addition to the mechanical composition of the soil the authors give a series of figures showing the results of capillary studies as follows:

A tube was filled with gypsum and another with dune sand. The lower end of each was placed in water and the height at which the water stood in each was noted once a day for 25 days. The results are stated in the following table in inches:-

	Gypsum	Sand
15 minutes	1.5	6.5
45 "	2.25	11.5
1 hour	3.00	13.0
2 hours	5.00	14.0
6 "	9.5	17.0
24 "	17.5	18.25
2 days	24.0	19.5
3 "	24.75	20.5
4 "	32.00	20.5
6 "	37.5	20.5
7 "	40.00	-
8 "	42.25	-
9 "	44.25	-
10 "	46.5	-
13 "	50.5	-
14 "	52.0	-
15 "	53.0	-
16 "	58.0	21.0

According to this, this soil has a high capillarity, a characteristic that as we saw illustrated with the soil from Repetek, is not general with gypsum crusts.

As one travels from northern Africa southward the Gypsum crust disappears, rarely being found south of the latitude of Minieh. From here southward the soils are uniform in character, contain no cementing[1] material of any kind and consist of rock debris as far as the 18th degree of latitude where a belt of still lower rainfall is reached. In the dry regions of the desert where the Gypsum and Lime crusts are absent, the Brown Protective Crusts appear, designated also as "desert sunburn" and "desert varnish". The Protective Crust was first observed by Humboldt[2] during his travels though he declared it merely as an apparent crust rather than a real one but later, in the 4th, 5th and 6th decades of the 19th century it was mentioned by many travelers[3] and investigators. Not until recent times however was it investigated in a thorough going way and its origin determined.

According to Johannes Walther his observations in Africa, America and Asia warrant the conclusion that the Protective Crust is a most important characteristic of the very dry regions of the globe and can therefore be considered as the special characteristic of such regions. The dryer the region and the more destitute of vegetation the better is the crust developed.

It is not always brown in color. It may be yellowish, glistening black or reddish.

Certain limestones are not well adapted to the formation of such crusts. Where such form they are light brown to light yellow except where fossils are exposed and in such cases the color is brown to blackish. Rocks high in silica develop a very thin brown coating. Silicious concretions and pebbles are distinguished from the light brown or yellow color of the rock in which they occur by their darker brown color. The feldspar crystals in the granite of western Texas become browner than the quartz and mica crystals. Pebbles and stone fragments are darker on the upper than under side.

Investigations in the deserts of Central Asia, undertaken by Obrutschew[4] showed the universal occurrence in this region also, of the Protective Crust and that it is better developed in the dryest regions where vegetation is scantiest. According to him

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1 W. F. Hume, The study of Soils in Egypt. Verhandl. der zweiten internationalen Agrogeol-Kongress, 1911.
2 Humboldt, Reisen im die Aequatorialgegend, 4.
3 See Du Bois, Tschermaks mineralogische und petrographische Mitteilungen. 22, H. 1, 1903.
4 Obrutschew. Report of the Imperial Mineralogical Society, 2 Series XXXIII, Part 1, 1895 (Russian).

insolation plays no important role, for stones and pebbles are covered on all sides by the crust. The difference in thickness of the crust on the northward and southward facing sides of stones is very slight. The crust is darkest and presents a most polished appearance on stones rich in silica and iron, such as quartzites, quartz schists, diabase, basalt, porphyry and porphyrite, while on coarse grained granite it is lighter in color, less polished and appears in the form of large and small spots.

The surfaces of limestone ledges and fragments containing iron bearing quartz veins are especially striking. The veins and lumps of quartz stand out as miniature ridges and hills above the other and softer parts of the rock which have a much darker color and more polished surface than the latter. The limestone surface on the other hand is rougher and has a brown or yellowish brown color without the polish.

The black color of the crust is best developed according to Obrutschew on the southerly slopes of the Tjan-Schan, in the Kuram-Tasch Canyon and in the desert region adjacent to the southern part of the Tjan-Schan range. In the canyon the rock surface, from the top to the bottom of the gorge 1500 to 2000 feet, is covered with a glistening crust. With one kind of illumination the rock surfaces appear to consist of millions of bluish flames while in another kind of light they are black like cast iron.

The protective crust as a rule is thin, usually one to two millimeters. It is so securely attached to the rock surface that it is impossible to remove it. The color of the rock has no influence on the color of the crust, that on both white and red sandstone being the same in color according to Walther.

If the crust be scratched with a metallic tool a red streak is obtained, though occasionally it is yellow or gray. The red color is due to the presence of hydrated iron oxides low in water (Turgite); the yellow color to Goethite, and the gray to manganese oxide. The mixing of these compounds brings out the various other shades of the streak. So far as the chemical composition of the Protective Crust is concerned it seems to consist, in addition to the pure iron and manganese oxides, of various intermediate stages of the development of these compounds.

According to Walther the protective crust is formed by the combined action of moisture and the sun's heat causing the solution of easily soluble substances in the rocks, their transfer to the surface of the stones and the precipitation on the surface of the salts thus dissolved. The more or less porous rocks absorb the dew and rain. The latter contain traces of soluble salts, especially sodium bicarbonate. The presence of these salts favors the decomposition of the rocks. Carbonic and phosphoric acid contained in fossils appear as solvents also. When stones containing these solutions are warmed the solutions rise to the surface by capillarity, the water

is evaporated and the dissolved material, mainly iron and manganese dioxide, is deposited on the surface of the stones. The silica of the crystalline rocks and the phosphoric acid of calcareous rocks appear in combination with iron and manganese. The oxides being hard and insoluble remain on the surface while chlorides are blown away or washed off. In the crusts of Mokkatam as much as 25% of P_2O_5 was found. It originates in the fossils within the rocks. This explains the darker color of the crust on the nummulites of the ledge surface, than on the rest of the rock, a fact cited by Walther.

Under the influence of rain, which occasionally falls in the desert the protective crust is partially destroyed, changing its color, losing its varnished appearance but later, under the influence of the sun's heat, the ozone of the air and also through the peeling off of portions of its surface it assumes again its typical appearance.

The descriptions of Linck[1] differ but little from those already given. He denies the influence of rain water in the formation of the crust, ascribing it to the influence of dew, carbonic acid, sodium chloride, and the high desert temperature. The oxidation, according to him, is due not only to the ozone of the air but to ammonium nitrate, whose fine crystalline dust is present in the air. Where rain falls frequently, no crust forms although the insolation may be the same as that in the desert.

This last conclusion of Lincks is not entirely correct for the investigations of DuBois[2] have shown that the crust is formed during the dry season, on rock ledges and pebbles, in the moist regions of the tropics (Surinam). He investigated here a long series of crusts, light brownish red on granite; yellow, reddish brown to black on medium grained granite; black on granite rich in mica and black smooth polished crusts on garnetiferous mica schist. The latter is present on stones free from garnet but in small amounts only. The black crust was found by DuBois on the feldspars of the Savanna sands also.

The various crusts are therefore a typical phenomenon of the desert in which they are widely distributed. They may occur sporadically in other regions when conditions are favorable. The thin lime crust found in steppes and semi-arid regions where a hard dense layer is formed on rock surfaces may be ascribed to such sporadic occurrences. In Saratow such crusts may be seen on the surfaces of non-calcareous rocks and on quartzitic sandstones (near Kamyschin). I have seen the Protective Crust in many places in the Gray Earth zone of the desert steppes of Turkestan as well as in higher and more moist regions.

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1 Linck, Jenaische Zeitschrift fur Naturwissenshaft 1900.

2 DuBois, Tschermaks mineralogische und petrographische Mitteilungen, 22 Heft 1, 1903. See Em. Haug also.

In addition to the varieties of Protective Crust already mentioned, which, especially the Lime and Gypsum crusts, have been insufficiently studied, silicious crusts are mentioned in the literature[1] also. These are least known of all. It is not known whether they are widely distributed or occur sporadically only, determined by special local conditions. It is not known whether these crusts are zonal in their occurrence as thought by Sibirceff, or intrazonal like the alkali soils. To solve these questions the desert soils must be more thoroughly investigated.

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7. Gordejew, Arb. der Naturforsch. Gesellsch. zu Saratow, 1903, 5.

8. Gordiagin, Arb. der Naturforsch. Gesellsch. zu Kasan, 1900, 34, 1901, 35, Nr. 2.

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[1] Kalkowsky, Die Verkieselung der Gesteine in der nordl. Kalahari, Mitteilungen des Kgl. Miner. Geol. Museum, Dresden, [illegible] 1901 (Russian).

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16. Muschketow, Turkestan, 1886, 1.

17. Neustrujew und Bessonow, Der Boden der zu bauenden Eisenbahnlinie nach Semipalatinsk -- Wjerny. St. Petersburg, 1908.

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SOILS DEVELOPED UNDER CONDITIONS OF EXCESSIVE MOISTURE

Of the two subgroups of this class, the Moor soils, with which we shall first concern ourselves, have been most fully investigated. They are most widely distributed in those regions that receive either very heavy rainfall or else are subjected to excess of moisture in the surface horizon by low temperature and consequent low evaporation. The latter condition is the most favorable one since heavy rainfall is usually associated with high temperature. In dry regions such as deserts, semi-arid regions and steppes, Moor soils occur very rarely since parts of these regions are rarely saturated with moisture. Where saturation does occur, as we shall see below, Moor soils are not developed, their place being taken by another group of soils, the alkali[1] soils.

Excess of moisture, the fundamental condition for the development of Moor soils, influences first and most important of all, the decomposition of the organic matter found in the surface and upper horizons of the soil profile. Good aeration of the soil cannot take place. The decomposition of the organic matter takes place under imperfect access of air. The organic material is not completely decomposed except through considerable periods of time. It proceeds very slowly. As it proceeds various gases, resulting from partial oxidation, are formed, such as Methan, hydrogen sulphide, phosphoretted hydrogen, nitrous oxide, nitrogen and others. Difficultly soluble nitrogenous and non-nitrogenous products accumulate; for example, organic acids (humus and the acids of the fat series) leucin, tyrosin, indol, skatol, etc. Only small quantities of nitrates and nitric acid are formed. Masses of material containing such bodies are unfavorable to the life processes of many bacteria and for that reason a great many bacterial processes are prevented. The products of partial oxidation that are unfavorable to bacterial life are destroyed by molds.

In Moor soils large amounts of humus accumulate, on account of the incomplete oxidation of the material, as well as half carbonized organic remains which still retain traces of their organic or vegetable structure. The excess of moisture influences the rapidity of leaching of such products of decomposition as become soluble.

Moor soils develop not only under the influence of downwardly percolating water but also under that of rising moisture, when the ground water level lies at shallow depth. In this way the actions of soil making process as well as soil structure are influenced in a characteristic way.

The morphological and chemical characteristics of those varieties of Moor soils occurring in the cool temperate zone have been thoroughly investigated. They are divided into two main groups,

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[1] The word "alkali" is used here in the American sense referring to the presence of salts in sufficient concentration to affect plant growth.

the true fresh water and moorland moor soils and the brackish and coastal moor or marsh soils. The many fresh water and coastal moor soils so widespread in occurrence in the Coastal lands of the North and Baltic seas have been described and separated into a number of varieties by German, Dutch and Danish investigators. In the third decade of the 19th century publications began to appear in western European literature, like those of Stelzner[1], in which the moor soils were discussed in a thoroughgoing way. During the 19th century these soils attracted a great deal of attention so that at present there is found in the literature of many countries the results of fundamental studies of these soils.

I. Moor Soils

Moor soils can be classified, best of all, on the basis of the character of the plant remains which occur in them. They can be divided for example into Peat, Muck, and Meadow soils as general groups within which various intermediate forms are found. The degree of decomposition of the vegetable matter and the mechanical composition serve as bases of classification.

The influence of decomposed or disintegrated organic matter on the texture and structure can be well seen where an upland soil changes by degrees into a Muck or Meadowland soil as often takes place along a gentle slope between the bottom of a basin and a wooded upland. The Muck changes gradually first to silty meadow land or silty Moor soil followed by argillaceous soils rich in organic matter and finally into typical Podsol. The characteristic features of the Moor soils gradually disappear and those of Podsols replace them.[2]

The profile of the typical silty moor soil such as level swamp, meadowland, lowland moor, valley swamp, is as follows:

A. The surface horizon is dark, often black and contains undecomposed plant remains. It is penetrated and spotted with brown stringers and spots of hydrated iron oxide. Occasionally the lower part of the horizon is darker than the rest because of the presence of carbonized plant remains. Since the deeper lying soil horizons are less accessible to the air than the surface horizons this organic material will decompose more slowly than that in the surface horizons. The thickness varies.

B. The second horizon, since it is exposed both to the percolating surface water and to the rising ground water and was formed under the influence of both, may be called the Gley horizon and is characterized by bluish, light blue and greenish colors.

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1 Stelzner. Möglinsche Annalen der Landwirtschaft, 20 and 31, 1827-28.
2 G. Tanfiliew, The Polar boundary of the Forest in Russia, Odessa, 1911 (Russian).

This color is due to the presence of ferrous iron compounds, such as vivianite, which are formed by the action of reduction processes due to the presence of an excess of moisture. Vivianite in an unaltered condition is white and becomes bluish with beginning alteration. As alteration proceeds the ferrophosphate passes through a series of intermediate stages into ferriphosphate. We shall deal with this matter more fully however under the discussion of the chemical characteristics of the silty swamp soils. At present we shall merely note that in the B horizon rusty splotches and streaks are often seen which have been formed in cracks and root cavities because of the more ready access of oxygen to such places. Silty swamp soils and the meadowland soils belonging in the same group are found as intra-zonal soils in the Podsol and Tundra zones. There are regions also in which such soils predominate. Our own far eastern territories, the Amur and Coastal regions, are of this character and the prairies of North America lying along the Mississippi are of the same type.

Large areas of the Seja-Bureja water-shed in the Amur regions are covered with dark meadowland soils made swampy by the influence of the heavy precipitation during the summer monsoons from the Pacific. Of the 20 to 24 inches of annual rainfall of this region about 16 fall in the summer and autumn. These soils have been mistakenly called Tschernosem or Tschernosem-like[1] soils by many investigators. Their profile is as follows:[2]

A. In moist condition black or very dark gray, structureless containing undecomposed organic remains. 25 cm. thick.

B. Bluish gray, not uniformly colored, dark colored lumps rich in humus project into the upper part from the A horizon. Porous not noticeably stratified. Hard dark brown Ortstein concretions are present. 20 cm. thick.

B_2. Yellowish gray, laminated. Breaks up into flat glistening porous pieces. Contains a number of hard Ortstein concretions. 20 to 30 cm. thick.

C. Yellowish brown sticky clay.

The absence of a well defined Gley horizon is due in our opinion to the over saturation of these meadow-land soils with percolating surface water only. Where these soils lie in depressed areas in which the ground-water rises to the surface highly definite and well developed Gley horizons are present.

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1 Glinka, K. Kurze Zuzammenfassung der Angaben ueber die Böden des weiten ostens (Vorläufige Mitteil.) St. Petersburg, 1910.

2 Tomaschewski, Vorl. Mitteil. der Organization und Vollziehung der Erforsch. in asiat. Ruszland, im Jahre 1910, St. Petersburg, 1911, p. 46-47. Idem Die Böden der Wasserscheide Seja-Bureja, St. Petersburg, 1912.

It was thought until recently that the processes of weathering in Swamp soils developed certain acids from the organic matter and that through their action the weathering of the silicates in such soils was like that taking place in the Podsols. The acids were called humus acids. Baumann[1] claims to have shown recently that the acidity of the swamp soils is not due to humus acids and furthermore that no such acids exist. It seems however that the idea of their existence is a correct one and that Baumann's conclusions may seriously be questioned.[2]

Water extracts of the swamp soils of eastern Siberia do not react sour, but because of the presence of bicarbonates they react alkaline. This fact led me, in association with the student Sutulow, to investigate a number of moor soils from the vicinity of New Alexandria. We became convinced that in these peat soils the mineral horizons as well as the swamp water gave a definitely alkaline reaction, the reaction of bicarbonates. The swamp soils of the Vistula valley also gave the following results:

			Alkalinity in HCO_3 on 100 grams of soil.
No. 1	Horizon	A	0.0203
	"	B	0.0407
No. 2	"	B	0.0294
No. 3	"	A	0.0095

In water taken from a sphagnum swamp a liter contained 0.0126 HCO_3 the upper peaty horizons reacted only feebly sour while the underlying gley horizons reacted faintly alkaline (100 g. soil = 0.005 HCO_3).

In general it is apparent that all soils, or at least individual soil horizons, when they stand for a long time in contact with water will react alkaline. In such cases an energetic hydrolysis takes place in consequence of which bases of the silicates as well as of the alkali salts of the organic compounds are split up. For the same reason the ground water of Podsol soils as well as the Gley horizons should react alkaline.

Stremme[4] and Endell[5] found that the acid reaction of swamp water was due to the presence of carbonic acid. According to them decomposition beneath swamps takes place mainly under the influence of carbonic acid and water containing bicarbonate. The aluminum

1 Baumann. Mitteil. der K. Bayer. Moorkulturanstalt. H. 3, 1909 Baumann u. Gulley, Ibid, H. 4.
2 See Glinka, Nouveaux coulements dans la pedologie. Pedologie 1910 No.1. Also A. Rindell, Internat. Mitteil. fur Bodenkunde 1911.
3 Wir wennen die reaction des wasserauszuges sauer, wenn sie nicht beim längeren Kachen des Bodens verschwindet; Siche Gedroitz,Die Methoden der chemeische Analyse.
4 Stremme. Zeitschrift fur prakt. Geol. 1908, 16, S. 122-128.
5 Endell, Neues Jahrbuch fur Min. 31 Beil. Bd. 1-54, 1910.

bearing silicates must decompose under these conditions to clay, a change known to be taking place[1]. The decomposition of basalt rock under the influence of swamp water was studied by Endell, his analytical data, calculated on a water-free basis, being shown in the following table:-

1. Fresh basalt.

2. Yellowish brown loam from a depth of 30 cm beneath a swamp.

3. Greenish loam from a depth of 1.25 m under peat.

	1		2		3	
	%		%		%	
SiO_2	40.06		63.66		71.76	
TiO_2	1.72		1.51		2.30	
Al_2O_3	7.97		11.76		13.76	
Fe_2O_3	3.47)	)11.70	10.77)	)12.61	2.90)	)5.13
FeO	8.23)		1.84)		2.23)	
CaO	12.54		2.93		3.35	
MgO	8.59		4.82		0.90	
K_2O	2.99		3.10		1.77	
Na_2O	6.76		2.46		1.41	
P_2O_5	0.57		0.43		trace	
SO_3	0.57		0.43		0.25	

With the leaching out of the iron oxide and the bases a corresponding enrichment of the alumina, silica and titanium oxide takes place. The mobility of the iron oxide is characteristic of swamp soils where conditions favorable to the formation of the ferrous compounds exist. As a result of this a series of iron compounds are found in swamp soils that are found in no other. Among these are Vivianite, mentioned on page 169, the sulphur[2] compounds such as FeS, FeS_2, and also $FeCO_3$, both crystalline and amorphous. The so-called rasen ore, sometimes found in the upper horizons of moor soils, is formed under the influence of rising water. The formation of Vivianite takes place through the action of ammonium

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[1] See Stremme, Zeitsch. fur prakt. Geol. 16, 122-128; Hahml. Journ. fur prakt. Chemie, 78-281 - Wüist. Zeitsch. fur Prakt. Geol. XV, I - Ramann, Bodenkunde 2 Auflage 1905.

[2] E. Palla, Neues Jahrb. fur Mineral., 1887, II, 6.

phosphate on solutions of the ferrous salts. It is possible that the phosphoric acid is formed by the oxidation of phosphoretted hydrogen, and that this process takes place through the action of micro-organisms. The transformations of phosphorus in soils is not yet well worked out.

Struvite also has been found in organic matter that has decomposed with insufficient access of the air. It is possible that in swamp soils ammonium compounds are more easily preserved than in soils to which the air has ready access, because of the very slow formation of nitrates. In this way the formation of ammonium phosphate is explainable. Since swamp soils dry out in summer and oxygen gains access more readily the ferrous compounds become oxidized. Pyrite and marcasite oxidize to iron sulphate, free sulphuric acid and a long series of simple and complex sulphates. By this means the leaching out of aluminum in the form of sulphate may take place from a swamp soil rich in iron sulphides. Vivianite may become oxidized, as stated above and may form a long series of products between the Ferro and the Ferriphosphates. Such compounds found on the Kertsch peninsula were investigated by Popow[1]. The Vivianite found there has the composition (Fe, Mn, Mg, Ca)$_3$ P_2O_8 · $8H_2O$ and is called by Popow Paravivianite. Its crystalline products of weathering are:

Kertschenite (Fe, Mn, Mg. Ca) $Fe_2P_2O_9 \cdot 7H_2O$ and
Oxykertschenite (Mn, Mg, Ca) $Fe_8P_6O_{28} \cdot 21\ H_2O$.

Other intermediate products were found at a later time.

It is possible that in swampy soils such intermediate compounds may be observed, a forecast that is partly confirmed by the occurrence in them of Beraunite, a ferriphosphate[2].

A whitish efflorescence of salts is formed on the surface of silty swamp soils in the northern part of Russia in dry summer weather. They have not been thoroughly investigated however. This phenomenon makes the soils on the swamps of northern Russia similar to the wet alkali soils of the Russian Tschernosem region to be discussed below.

The swamp soils of western Europe contain, of the more or less soluble salts, the sulphate of magnesia, lime and iron protoxide[3] and the sulphate of ammonia[4], calcium oxalate[5], and oxalic acid; iron protoxide and other salts have been found.

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1 S. Popow. Nachrichten der Kais. Akademie der Wissensch. 1907.
2 J.M. Van Bemmelen, Zeitsch. fur anorg. Chemie, 1900, 22, 313-379.
3 Mårcker, Zeitsch. der landwirt. Zentralverceus I. Prov. Sachsen, 1874 - J.M. Van Bemmelen, C.C. und Landw. Versuchst. 8.
4 Sprengel, Erdmanns Journal fur techn. and Oekonom Chemie, 1828, T II and III; Bodenkunde 1837, Van Bemmelen, as above.
5 Schmoger, Landwirtsch. Jahrbuch, 1895.

The compounds in which the potash[1] and phosphoric acid[2] occur in swamp soils have been studied by Wicklund. At least a part of the phosphoric acid forms a constituent of Nucleine[3].

In the lower humus horizons of the swampy soils marl beds are often found, a feature characteristic of the sub-group of peaty swamp soils to be discussed later. In the swamps of Bavaria the occurrence of the marl bed is very wide spread and is called "Alm". Sendtner[4] is of the opinion that the word originated from the expression "alba terra". The origin of the "Alm", consisting of lime carbonate with some magnesium carbonate, clay, phosphoric acid and organic material is not fully explained. Roth[5] was of the opinion that when the organic acids, set free by the decomposition of organic matter such as humic, crenic and apocrenic acids, act on limestone or calcareous soil, the ammonium-calcium double salt seems to be formed which is later transformed into the amorphous pulverulent calcium carbonate. On the surface and in the interior of the peat deposit such material often appears both as a mere white coating and as a rather massive layer. In peat bogs lying between Kirchdorf and Hersten lake (Bern) Brunner[6] found a 2 to 2.5 foot layer on top of the clay composed of amorphous carbonate of lime and with small amount of SiO_2 but free from infusorians. Senft[7] found, in the vicinity of Eisenach a slimy doughlike mass, under a peat layer, which when exposed to the air fell into a brownish-white coarse grained sand. Sendtner says that "Alm" forms the substratum of all the swamps of southern Bavaria and occurs as veins and streaks in the peat. In dry condition it constitutes a white loose sand, in wet condition a jelly-like mass.

In some cases the lime carbonate deposits in swamp soils are to be considered as deposits of the lakes in which the swamps have been developed. On the lake bottom a calcareous deposit, the lake chalk, is often formed through the action of water-loving plants. On the leaves of the plants the calcium carbonate is precipitated as a thin layer. Kerner noticed that a leaf of Potamogeton lucens weighing 0.492 grams precipitated 1.04 grams $CaCO_3$. The lime carbonate in other cases is precipitated[9] as a tuffaceous spring deposit and in addition to this its segregation by the action of soil processes is possible.

1 Wicklund, Landwirtsch. Jahrbuch, XX, 1891.
2 Wicklund as above, Schmoger, as above, Tacke und andern.
3 Schmoger as above.
4 Sendtner, Die Vegetations verhältniss Sudbayerns, 1854.
5 Roth, Algemeine und Chemische Geologie, I, 1879 S. 595.
6 Brunner, Mitteil. der naturwischaftliche Gesellsch. Bern 1849,123.
7 Senft, Zeitschr. der deutsch. geolog. Gesellschaft. 1851.
8 Ramann, Bodenkunde 2 Auflage 1905.
9 Sendtner, Die Vegetations verhaltnisse Sudbayerns, 1854.

The development of the characteristics of silty swamp soils as they have been described above is dependent upon the degree of decomposition that has been reached. Many features which are well developed and prominent in the swamp soils, are less well defined in soils with less well developed swamp characteristics such as the meadow land soils of Seja-Bureja in the Amur region. Since no complete analyses of these soils can yet be found in the literature I shall give here the results of the investigation of these soils carried out by the scientific expedition organized for that purpose in 1910. The meadow-land soils of the Seja-Bureja water-shed are noted for their fineness of grains as is shown by the following table:-

No. 34	1 to 0.25 mm %	0.25 to 0.05 mm %	0.05 to 0.01 mm %	less than 0.01 mm %
Horizon A (0 to 15 cm)	3.00	10.00	29.00	58.00
" A (15 to 30 cm)	3.50	9.00	23.50	64.00
" B (30 to 45 cm)	3.00	6.00	21.00	70.00
" B' (45 to 60 cm)	3.00	5.75	20.00	71.25
" C (---)	2.50	10.25	23.00	64.25

Horizon A has a lower percentage of fine grained constituents than horizon B. The total quantity of silt and clay in horizon A ranges from 87 to 87.5 per cent of all constituents, in horizon B from 91 to 91.25 per cent and in horizon C to 87.25%. Some translocation of material from horizon A to horizon B has taken place and the latter is to be regarded, because of this as an illuvial horizon. The chemical composition however has remained practically unaffected by this process, as is shown in the following table:

	A 0 to 15 cm %	A 15 to 30 cm %	B 30 to 45 cm %	B 45 to 60 cm %	C %
Water at 100° C	6.38	5.60	5.70	5.96	6.26
Humus	8.48	3.47	2.50	1.18	0.97
N	0.13	0.06	0.05	0.05	0.03
Loss on ignition	12.89	7.27	7.20	6.52	5.47
SiO_2	60.26	63.91	63.90	63.67	64.28
Al_2O_3	16.07	17.32	17.65	17.71	17.95
Fe_2O_3	3.68	4.99	4.91	5.83	6.39
Mn_3O_4	0.24	0.05	0.49	0.13	0.05
CaO	1.75	1.35	1.06	1.06	1.07
MgO	0.55	0.76	0.49	0.87	0.86
K_2O	2.50	2.50	2.25	2.20	2.23
Na_2O	1.67	1.59	1.50	1.51	1.66
P_2O_5	0.14	0.09	0.11	0.11	0.06

Without calculation on a water and humus free basis it is seen that the amount of SiO_2 and Al_2O_3 in all the soil horizons and in the parent rock C are almost equal. The lime accumulation in the upper layer is connected with the accumulation of humus. The iron oxide has been partially removed from the upper horizons. These features are characteristic of soils weathered under swamp conditions, even though no leaching out of the bases or accumulation of silica in the weathered horizons can be detected as was thought to be the case by Stremme and Endell.

The analyses of the swamp soils from the Mogotschi Valley in Transbaikalia[1] reported below are like the analytical data for moor soils reported by Endell:

[1] K. Glinka, La Pedologie, 1911, No. 2.

	1 %	2 %	3 %	4 %
Water at 100° C	6.18	4.43	2.31	2.28
Loss on ignition	18.65	10.32	3.69	3.04
SiO_2	50.16	55.58	53.08	54.49
Al_2O_3	16.46	17.33	20.89	19.89
Fe_2O_3	6.39	6.94	10.58	10.54
Mn_3O_4	0.15	0.07	0.11	0.15
CaO	2.62	3.34	4.98	5.73
MgO	1.29	2.05	1.65	2.07
K_2O	1.72	1.63	1.32	1.34
Na_2O	2.39	2.70	3.11	2.57
P_2O_5	0.37	0.26	0.38	0.34

1. Horizon A_1 of the swampy meadowland soil
2. " A_2 " " " " "
3. " B " " " " "
4. Parent rock (loam)

When calculated on a water and humus free or, in other words, a pure mineralogical basis the above analysis stands as follows:

	1 %	2 %	3 %	4 %
SiO_2	61.50	61.82	55.25	56.10
Al_2O_3	20.17	19.27	21.73	20.47
Fe_2O_3	7.83	7.71	11.00	10.85
Mn_3O_4	0.18	0.07	0.11	0.15
CaO	3.21	3.71	5.96	5.90
MgO	1.58	2.28	1.71	2.13
K_2O	2.10	1.81	1.47	1.38
Na_2O	2.92	3.00	3.23	2.64

The water extract of the meadowland soils from the Seja-Bureja watershed gave the following results:

	A 0 to 15 cm	A 15 to 25 cm	B 25 to 45 cm	B 45 to 65 cm	C
Total alkalinity	0.0062	0.0058	0.0034	0.0038	0.0034
Alkalinity of the alkali bicarbonates	0.0050	0.0034	0.0026	0.0026	0.0026
Alkalinity of the bicarbonates of the alkaline earths	0.0012	0.0024	0.0008	0.0012	0.0008
Residue on drying	0.0660	0.0404	0.0252	0.0222	0.0264
Mineral matter	0.0178	0.0118[1]	0.0096	0.0116	0.0096
Loss on ignition	0.0483[1]	0.0286[1]	0.0156	0.0108	0.0168
SiO_2	0.0016	0.0016[1]	0.0026	0.0015	0.0010
$Al_2O_3 + Fe_2O_3$	0.0041	0.0019[1]	0.0012	0.0010	0.0010
CaO	0.0048	0.0028	0.0020	0.0018	0.0030
MgO	trace	trace	-	0.0003	0.0004
K_2O	0.0011	0.0010	0.0011	0.0008	0.0007
Na_2O	0.0028	0.0021	0.0016	0.0008	0.0011
P_2O_5	0.0006	trace	trace	trace	trace
SO_3	0.0014	trace	trace	0.0008	0.0009
Cl	0.0012	0.0018	0.0006	0.0014	0.0007
Color	Very faint yellowish	Almost colorless	Almost colorless	Colorless	Colorless

The most characteristic feature of the water-extract is its alkalinity and a marked predominance of soluble organic matter in the upper humus horizons.

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[1] Mean of two determinations.

The alkaline character of the water-extract of swamp soils explains the brown color of the streams originating in swamp areas. In an alkaline medium the so-called Apocrenic and humic acids pass into the "Sol" condition and into pseudo-solution. The waters of the northern swampy zones as well as those of the tropics are characterized by their brown color. The color disappears in calcareous regions only where the lime transforms the humic matters into the "Gel" state or combines with it to form salts. In northern regions as well as in the tropics the soils react feebly alkaline, in the latter case this is true of all soils, in the former, of swamp soils only.

Peaty swamp soils differ in their profile very little from the silty swamp soils. In the place of the silty horizon of the latter there appears a massive peaty horizon very rich in organic matter. The organic matter is not so well decomposed as in the silty swamp soils, a matter dependent in part on the moisture present. This latter accumulates because of the hygroscopic character of the mosses.

The organic constituents of the peat horizons can be well seen in the following table:[1]

C	H	O	N
7.03 (61.13 to 50.98)	5.79 (7.40 to 4.63)	35.58 (40.88 to 31.03)	1.60 (2.54 to 0.87)
7.20 (60.94 to 54.45)	6.61 (7.55 to 5.21)	34.74 (37.86 to 30.32)	1.95 (2.91 to 1.41)
4.18 (61.10 to 44.78)	5.67 (7.37 to 3.85)	37.27 (47.62 to 28.48)	2.88 (4.28 to 1.80)

The average composition of the ash of the same peat is shown in the following table:-

K_2O	P_2O_5	CaO
1. 0.08 (0.01 to 0.11)	0.11 (0.04 to 0.22)	0.52 (0.22 to 1.01)
2. 0.10 (0.02 to 0.13)	0.13 (0.07 to 0.22)	1.38 (0.55 to 3.21)
3. 0.10 (0.03 to 0.25)	0.16 (0.06 to 0.47)	2.95 (0.49 to 6.68)

1. Sphagnum peat; 2. Mixed peat; 3. Grass peat.

[1] W. Bersch, Zeitschr. fur Moorkultur und Torfwesen, 1907, 5, 65.

Occasionally black segregations of Dopplerite[1] occur in peat. According to Bersch[2] it occurs in peat in Austria in many places, either filling cracks or coating remains of roots. While fresh it is a black soft elastic body, but on drying it becomes a quite hard, obsidian-like mass with conchoidal and shelly fracture.

In air dry condition it has the following composition.

H_2O	18.08 %
C	43.53 "
O	31.09 "
H	3.24 "
N	0.79 "
Ash	3.27 "

The ash and water free substance contains:

C	55.31 %
O	39.57 "
H	4.12 "
N	1.00 "

The content of air in the peat swamp soils is usually smaller than in swamps in which the organic matter is derived from moss, a fact established by Vageler[3].

The "hochmoor" peats are very low in salts and especially so in lime as can be seen in part by study of the ash analyses given above. Such peats are formed mainly from Sphagnum.

The profiles and other features of peat soils are similar to those of the silty swamp soils.

II. Marsh Soils

On flat coastal lands such as those along the North sea and in places along the Baltic, where marine deposition takes place at the mouths of rivers swamp soils, called marsh soils, are developed. The German word "Marsch" (plattdeutsch Mar, English Marsh) has according to Stelzner the same root as the latin word Mar. Consequently one should include in Marsh soils only those whose parent

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1 Früh, Ueber Torf und Dopplerite, Zurich 1883. Aleksiejew. Mining Journal, 1889, I, 301 (Russian)

2 Bersch, as above, page 195.

3 Vageler, Mittl. d. Kgl. Bayer. Moorkulturanst. München, ... 1907, I, 1.

rock was built, at least in part, by the sea. In literature however no such restriction exists for the term is applied to swamp soils developed on river deposits as well as those developed on marine deposits.

The marine deposits on which marsh soils are formed consist not only of inorganic material but of the remains of plants and animals also. There are Algae, diatoms, sometimes also the remains of other plants occasionally coming from the land. The animal remains consist of shells of Rhizopods and other organisms. All these materials appear as fine mud which exhibits very little trace of organic structure either animal or plant. The marine mud rich in ground up or decomposed organic matter is laid down by the sea during the summer. In winter on the other hand most of the deposition of inorganic material takes place. The alternation of light colored and dark colored layers in all exposures of a good marsh section is explained in this way.

On being elevated above the reach of low tides salt-loving plants soon appear. So soon as it is raised enough to be above tidal influence Poa maritima appears also. The meadow vegetation develops only after the elevation amounts to some three or four feet above sea level and the surface becomes relatively dry[1]. In northern Russia the meadow region which is covered at high tide is called "Laidy". It is covered with Plantago maritima, Triglochin maritimum, Pisum maritimum Alisma plantago[2], etc. From this group of plants it is evident that the young marshes contain considerable quantities of sea salt. Sometimes the salt disappears by natural processes and many times the disappearance is hastened by the use of embankments which prevents the access of sea water.

The formation of moor soils cannot begin until the marine deposits become covered with vegetation. In case an unbroken grass cover is formed soil development proceeds with energy. The further development of marsh soils corresponds to that of the meadow soils. The general characteristics of old marsh soils are essentially like those of the silty swamp soils and those of the meadowland soils. The West European investigators look upon the whole deposit from top to bottom as soil and often describe their profiles to great depths. In this way however they include in one description the soil and parent rock which has never been influenced by soil forming processes[3].

In order to give a complete description of the soil profile, the parent rock and the subjacent strata we shall give Van Bemmelen's[4] description of the marshes of the Netherlands. These

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1 Stockhard, Der Chem. Ackersmann, 1866 - Warming, Geographie der Pflanzen, 1901.

2 Tanfiliew, Die polar Grenze des Waldes in Ruszland usw. Odessa, 1911.

3 Stockhard, l. c. - J.W. Van Bemmelen, Landw. Versuchstat. 8. - Virchow, Landwirtsch. Jahrbücher, 1881.

4 J.M. von Bemmelen, l. c.

deposits are argillaceous in the upper and sandy in the lower part.

In the central part of the province of Groningen soils are found whose surface horizon is called "Roodorn". In places it has a reddish color due to the presence of hydrated iron oxide, is rich in humus and reacts faintly acid[1]. Beneath this surface horizon lies the "Knick" 0.2 to 0.4 m thick which consists of the true parent rock of the marsh and contains concretions and spots of iron oxide. The upper horizon of the "Knick" corresponds to the second horizon (B) of the meadowland soils. The whole "Knick" layer consists mainly of mineral material but contains some organic matter. Its content of humus amounts to about 5.5%. This has apparently not originated through the processes of soil formation but was deposited with the mineral matter as marine deposit. Occasionally the "Knick" is thicker (1 to 3 meters) becomes richer in lime with depth and passes into a special soil layer the "Wuhlerde". In places this clay is rich in gypsum and other sulphates. Whether the gypsum is a product of soil forming processes or is a product of geological processes which took place earlier is not entirely clear. Beneath the "Knick" lies the "Darg", a material sometimes very rich in organic substances formed by marine action.

In the literature of Western Europe there are still other terms applied to the separate horizons of the soil and parent rock which we shall not use here. Of the various constituents of the several marsh soil horizons Van Bemmelen mentioned Pyrite, Vivianite, the soluble salts of iron, sulphates of Alumina and Magnesia. All these compounds occur, as we have seen, in fresh water swamp soils.

The profile and composition of the swamp soils and wet-land soils of other regions of the earth have been investigated very little, but there can be no doubt of their occurrence in other regions including the areas of high rainfall in the tropics. In my Russian pedological lectures[2] I have described two kinds of swamp soils from tropical latitudes which are analogous to the fresh water swamp soils and the marsh soils mentioned above. The mangrove soils of the coasts are placed in the group of marsh soils. This has been done mainly on theoretical grounds rather than on facts. My assumption of the existence of two groups of tropical swamp soils has recently been confirmed by observations by Mohr[2]. At an elevation ranging from 50 to 200 meters in Hinterdeli and Serdang he found an accumulation of humus which is very much like the humus in the Alps as described to him by Ebermayer[4] and referred to by Ramann[5]. In a

1 The cause of the acid reaction has not been determined. The red color of the Roodornes is really to be explained by the formation of the iron oxide before the sea salt has all been leached out. See Stremme. Zeitschrift. fur prakt. Geologie, 18, 1910. H. I.
2 K. Glinka, Bodenkunde, 1908, S. 484.
3 Jul. Mohr. Bullet. du Departem. de l' agriculture aux Indes neerlandaises, No. XVII Buitenzorg, 1908.
4 Ebermayer, Wollnys Forschungen, 10 S. 385.
5 Ramann, Bodenkunde, 1905, S. 177.

valley parallel to the coast a large accumulation of calcareous tufa has been deposited from springs and at the present time a massive dark brown fatty humus mass, free from sand and clay is found between the masses of sinter. This soil gives a low yield of tobacco of poor quality because of its high content of SO_3. On account of the latter its burning qualities are poor and the color of the ash is black.

According to the same author a sample of soil from Boutain, West Java was received at the laboratory in Buitenzorg. It consisted of moist silty material from a rice field and had a strong odor of sulphuretted hydrogen. It was dense black but on treatment with hydrochloric acid became brownish with a strong development of sulphuretted hydrogen. On analysis the latter amounted to about .53% of the total dry matter of the sample. Iron sulphide was present corresponding to 1.37% of FeS. In this case apparently a considerable sulphate reduction had taken place. The loss on ignition amounted to 36% of the dry matter and a strong peaty odor was developed in the ignition. The residue consisted of argillaceous material.

According to Mohr, swamp development on the tropical sea shore is due to rivers. The rivers bring down quantities of mineral matter which on deposition forms deltas and other forms of accumulated material. These accumulations tend to shut off the influence of the sea and to favor the development of swamps. Around the river mouths a net work of river channel distributaries develop bounded by banks of sand, gravel and mud. The river water however is not ponded but flows onward to the sea, though the current may be sluggish. This more or less extensive area of sand, gravel, silt and clay with its numerous river channels is the seat of swamp development and the formation of swamp soils. The further any spot of this kind lies from the sea the more is it free from salt water influence. The humus horizons that develop here do not form layers of peat like that formed in the flat swamps in cooler or cold climates. They are more thoroughly disintegrated and decomposed. There are less remains of plant tissue, the cellulose seems to have disappeared. There is present however, a kind of material which offers more resistance to disintegration. This is made up of resin. The greater part of the forest trees in such places are rich in resin and increase in richness as the sea is approached. The resin becomes dark with time but does not decompose. The swamp soils which develop furthest from the sea become gradually dry, black, loose and friable and capable of cultivation. They are known as "Paya".

The development of mangrove soils, the gradual sweetening of mangrove swamps and their change to soils capable of cultivation are similar to the changes taking place during the natural development of the marsh soils of Western Europe into polder and meadowland soils. At the present time we know very little of the chemistry of tropical swamp soils. If one judges from the evidence presented by Mohr of the presence of sulphur compounds he will

conclude that certain reduction features of these swamp soils of the tropics correspond to those of extra tropical regions, but it does not follow from this that all the other features or processes of development are identical in both groups.

It is possible that the processes of decomposition of the silicates and aluminum silicates in the tropical swamp soils extend to the formation of free aluminum hydroxide, and that in general they proceed with greater energy than in the swamp soils of our latitudes. The investigations of Munz and Rousseau[1], who proved the occurrence of aluminum hydroxide in the dark colored soils of Madagascar, point to the possibility of such a result.

We pass now to the consideration of other subgroups of soils which for the present we include in the general group of soils developed under conditions of excessive moisture. These are the little known soils of the relatively dry tundra[2] and those of high mountain regions.

Ssukatschew[3] has recently described the tundra to the north and northeast of the Urals between the Kara and the lower course of the Obi. According to him the soil varies in this region with variation in relief, with the accompanying variation in moisture, and with that of the parent rock. Only on the high plateau where no accumulation of water takes place is there development of typical tundra. He describes a profile of the typical soil that was examined in dry tundra on the upper course of the Lubi-Jaga. The micro-relief is slightly hilly, a feature characteristic of this tundra. The cover of grass is neither dense nor high, and consists mainly of Carex rigida, Good, associated here and there with Polygonum viviparum L., Festuca ovina, s.l. Occasional small plants of Betula nana L., and arctic Salices.

The soil is covered with an unbroken layer of moss ranging from 2 to 3 cm. in thickness, mainly made up of Hylocomium sp., Aulacomnium sp. and others. Sphagnum is absent entirely. The soil profile is as follows:

1. Grayish brown humus horizon. It contains in places plant remains showing very little signs of decomposition. 3 cm thick.

2. Yellowish gray, occasionally grayish brown, ochreous, loose, loamy horizon. 2 to 3 cm thick.

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1 Munz and Rousseau, Bull. du Ministere d' Agriculture, 1900, No. 5.

2 We speak of dry Tundra meaning tundra occurring at the higher elevations, for that at lower elevation is covered with swamp soils similar in some of their characteristics to those of forested regions. In the river valleys of the tundra beautiful meadows are developed. Their soils must be similar to those of the forest zone

3 Ssukatschew, Zur Frage vom Einfluse des gefrorengen Horizonentes au den Böden. Ber. der. Kais. Akad. der Wissensch. z. St. Petersburg, 1911.

3. Gray blue horizon, uniform and composed of a very sticky loam. It flows readily into an opening made through or into it. In a single mass sample it is fluid in appearance. The boundary between it and the overlying and underlying horizons is very sharp. 8 to 10 cm thick.

4. Brownish yellow loam, similar to horizon 2 but more compact. 2 to 3 cm thick.

5. Compact brownish gray horizon that shows no tendency to fluidity. At a depth of 40 to 60 cm dark spots apparently organic are often seen. Fragments of stones are sometimes present. At a depth of 79 cm from the surface the horizon was frozen but the characteristics of the horizon extended unchanged 10 cm deeper. The hole was 89 cm deep.

Ssukatschew remarks that the thickness of the bluish gray horizon No. 3 is thicker where more moist and thinner where less moist. When the soil becomes sandy the horizon disappears completely. That is readily conceivable for this horizon is a product of reduction processes, corresponding to those which take place in horizon B of the swamp soils. For this reason the bluish gray horizon is comparable to horizon B in the swamp soils.

When this horizon is absent, the tundra soils apparently are similar to those of the Podsol group. There are observations on record warranting the belief that Podsol forming processes are in operation in the tundra region though they do not predominate.

The soil building processes operating in the tundra are often entirely concealed by the mechanical disintegrating processes brought about by freezing. The half liquid, gray blue horizon may be compressed, reduced in temperature below 4° Cent. and diminished in volume in those cases where the underlying permanently frozen horizon lies near the surface, and the overlying horizon becomes frozen in winter. Since the gray blue horizon contains air it seeks an outlet under such conditions, breaks through the overlying horizon and thus reaches the surface. Where the surface horizon consists of a tough sod cover however the flowing material does not reach the surface but collects beneath it forcing it upward into a low hill. In the first case, where the material reaches the surface a spotted tundra is formed through the formation of bare areas due to the pouring out of the semi-liquid mass. In the latter case a "gewölbte" or mound dotted[1] tundra is developed. The above explanation of Ssukatschew is supported by the presence, established by observations, of a frozen horizon in and between the hillocks and of the change in depth of the frozen horizon with the seasons.

[1] Prochorow and his associates have observed the same or similar phenomenon outside the Tundra zones in the Amur region. It is possible that such phenomena may be found in many parts of the forest zone where permanently frozen horizons exist.

These processes mix the soil horizons and special care is necessary in order to be able to determine in any particular case what features are the product of soil forming processes and what are due to the mechanical eruption of the half fluid mass of the blue gray horizon.

The blue gray horizon, forming as it does the characteristic feature of the tundra soils, reacts faintly alkaline, its alkalinity corresponding to 0.006% HCO_3. The same reaction is given by horizon 5 of the tundra profile given above. The brown horizon No. 4 reacts faintly acid, nearly neutral. These reactions suggest a relationship between the soils of the tundra and those of the silty swamp soils.

According to Tanfiliew[1] in the mountain region of Timan, steep slopes may be found consisting of consolidated rocks which are covered with a coat or cover of Cladonia rangiferina, Stereocaulon paschale and Cetraria nivalis spotted with areas of gray moss. On the smooth areas the rocks are covered with a 5 cm sod or turf sticking fast to the rock surface consisting mainly of interlaced branches of Empetrum nigrum with Trichocolea tomentella, Jungermannia Sphaerophoron, Cladonia rangiferina and Festuca ovina. This turf is not easily destroyed and it will often separate or pry off large fragments from the surface of a rock ledge.

The soils of the high mountains can be separated into two groups: (1) Peaty soils and (2) Mountain meadow soils. Representatives of them are found in the Caucasus on top of the Zchra-Zkaro and Ali-Bek. The profile in both localities is the same. The soil lies on consolidated rocks and appears very imperfectly developed. Its surface horizon consists almost exclusively of interlaced grass roots and has a dark brown shade. The fine grained material which can be isolated from the plant remains that are still recognizable as such is extremely light in weight, and almost half organic in origin. The color shade of the underlying horizons is brownish and becomes lighter downward. It is, like the surface horizon, very light in weight. Beneath this lies the consolidated parent rock. Similar bodies were described by Sacharow[2] under the name Eila-soils from the main chain of the Caucasus[3] and by Neustrujew[4] from the mountains of Karatau and the Talassian Alatau. The soils from the last mentioned locality according to the analytical results of Neustrujew are not especially rich in humus:

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1 Tanfiliew, Die Polare Grenze des Waldes, Odessa, 1911.
2 Sacharow, "La Pedologie" 1906, 1-4 (Russian)
3 See also Dokutschajeff, Bericht der Kaukas. Sect. der Kais. Geogr. Gesellsch. 1899, Lief III.
4 Neustrujew, Reports of the Scientific expedition for the investigation of the lands to be opened to colonization in Asiatic Russia. Soil Investigation, 1908 Part 7, 1910 (Russian).

Loss on ignition	16.58
Humus	9.40
Moisture	4.47

The mountain meadow soils of the Caucasus which have been seen by us on Ali-Bek near Daratschitschag in the vicinity of Erivan do not lie so high as those of the soils last mentioned (2700 M on Zchra-Zkaro and Ali-Bek). Bogoslowski[1] was the first scientist to recognize the special features of this soil which he found on the bare top of Jajla in the Crimea and in part on the top of Pilatus at Luzerne[2]. The upper horizon of this soil is rich in humus, occasionally black in color and similar to Tschernosem in structure a and color. The loam underlying it has no trace of lime carbonate however, while the presence of the latter is a characteristic feature of the Tschernosem. In the fissures and root passages the brownish coatings characteristic of forest soils are absent. According to Neustrujew[3] this soil on Karatau has developed on loamy deposits of considerable thickness. They have a very thin dark layer on the surface, formed by the dark gray turf horizon, reaching a thickness of 1 to 5 cm and filled with a great many roots. Beneath it lies a light brown clay mass containing roots and iron spots, separated by a sharp line from the overlying horizon. It is cloddy or pealike, becomes lighter in color downward passing into brown, occasionally porous, clay with yellow ochre-colored spots. The following analytical data for this soil is taken from Neustrujew:

Locality	Depth in cm	Humus %	Water at 100° C %	Combined Water %	Loss on ignition %
From the vicinity of Mt. Myn-Dshilka in Karatau. Elevation about 1800 m	0 to 3	25.24	5.06	2.99	27.98
	6 " 10	6.96	2.56	1.99	8.84
	20 " 30	3.30	2.00	2.78	6.04
	55 " 60	1.38	1.57	2.10	3.48
	87 " 95	1.16	1.63	2.25	3.41
From Dongulek-ssas in Talassian Alatau. Elevation about 2500 m.	0 " 2	28.62	6.62	4.49	32.64
	3 " 8	13.91	4.57	2.89	16.58
	8 " 13	8.60	4.04	1.96	10.40

1 Bogoslowski, Bulletin of the Geological Committee of St. Petersburg, 16, 1897. No. 8-9 (Russian)
2 Bogoslowski, La Peodologie, 1902, No. 4
3 Neustrujew - see above.

According to Neustrujew all mountain soils are formed in the presence of excessive moisture. It is not present permanently according to him but periodically, especially for the upper soil horizon. We must on our own part state that such a periodicity is characteristic of meadowland soils. They are wet during the winter but in summer they lose their excessive moisture.

Prassolow[1] obtained results for the humus in the mountain meadow soils of Tian-Schan mountains similar to those obtained by Neustrujew on Karatau. The soil described by him may be regarded, on the basis of its occurrence, as intermediate between meadow soils and peaty mountain peak soils.

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[1] Prassolow, Arb. der Boden expedition zur Erforsch. der zu Kolonisierenden Region des Asiatischen Ruszlands. Bodenforschungen, 1908, Lief 5, 1909.

SOILS DEVELOPED UNDER CONDITIONS OF TEMPORARY EXCESS OF MOISTURE OF EITHER SOIL OR SUBSOIL

These soils belong to the important group of alkali soils. They are known to occur in various climatic zones and in those parts of the zones where the precipitation is relatively light. They originate usually in topographic situations similar to those in which swamp and meadowland soils develop. This occurrence is especially true of those alkali soils known in the older Russian literature as structureless alkali soils and in recent times as "Solontschak".

In addition to the structureless alkali soils Russian investigators have differentiated another variety with well defined structure known now as "Solonetz". Both varieties occur scattered widely over the Tschernosem, Chestnut Colored, Brown and Gray soil zones as isolated patches of widely varying size. Associated with the fully developed members of the group are a series representing transition stages between them and the zonal soils of the zones in which they occur. These transition soils are called Solonetz-like and Solontschak-like soils.

The soils of this group have a high content of soluble salts, at times great quantities. The latter form efflorescences, and at times also crusts of considerable thickness on the surface. In many cases their quantity is very small and it is at times difficult to detect their presence by analytical methods even though, as we shall see below, they have influenced the chemistry and morphology of the soil.

Whence the salts come and why they are found in the surface horizons of the earth's crust are questions which are answered by various investigators in various ways. Some maintain that the salts originate from geologically old salt deposits or from marine deposits containing very small amounts of salts which are leached out by water and recrystallized.[1] Von Schlagintweit-Sakünlünski[2] concludes, on the bases of studies in the high plateau of Thibet, that salt lakes are formed through the gradual concentration of ordinary surface water and the drying up of the lakes causes the precipitation of the salts. According to Povepny[3] every enclosed basin will in time become impregnated with salt through the accumulation of salts contained in the atmospheric precipitation.

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1 W. Parish, Buenos Aires and the Province of the Rio de la Plata. London, 1852. - Philippi, Reise durch die Wüste Atakama, 1860, S. 134. Tschudi, Reisen durch Sudamerika, 5, 292, (1-5, 1866-1868) Brackenbusch, Bol. de la Acad. Nacional de ciencias en Cordoba, 1883, V 240 - Döring, Ibidem, 1884 VI, 272.

2 Von Schlogintiweit, Sakünlünske, Abhandl. der bayr. Akad. der Wissensch. 1871, XI, 115.

3 Pošepny, Stizungsbericht d. Kais. Akad. der Wissenschaft in Wien, 1877, LXXVI.

Wyssotski[1] and Dimo[2] are also of the opinion that the salts come from the air. Many investigators look upon the salts as the product of weathering of the various crystalline and sedimentary rocks.[3] Boussingault[4] suggests a volcanic origin, through the action of hot springs in volcanic regions.

Only those views which look to the combined influence of weathering processes and atmospheric precipitation for the sources of the soil salts can have general significance. In isolated cases salts may be accumulated from each of the sources mentioned, but when reference is made to salts which are distributed over wide areas in which neither marine deposits nor volcanic accumulations are present, their accumulation can be explained only through weathering and transportation by means of winds, or atmospheric precipitation. Atmospheric precipitation may occasionally bring chlorides and sulphates as well as nitrates.

Winds carry various salts, at times even important amounts of lime carbonate as well as mineral powder in the form of dust. Salts, especially sodium carbonate,[5] are supplied also by weathering and the processes of the decomposition of vegetable matter. The processes of plant decomposition are, in dry regions, of especial importance in the formation of soil salts, since the decomposition of the silicates in such places is very slow.

The volcanic processes and the processes of soil formation must be looked upon as the original causes of the formation of salts on the earth's surface and of the two the place of greatest importance must be given to the soil forming processes since they operate over the whole earth. Atmospheric processes merely transport the salts already formed. If two soil profiles of the same type but derived from different rocks show on examination an accumulation of salts in the same horizon, the presumption, strong enough to amount practically to proof, points to their accumulation as a product of factors common to both soils, the soil forming processes rather than to factors not common to both, the

1 G. Wyssotski, La Pedologie, 1899, 1900, 1903.
2 Dimo, Halbwüstenbildungen im Süden des Tsarizin-Kreises, Saratow 1907.
3 Richthofen, China, I, 1877.- Burmeister, Descr. Phys. de la république Argentine, 2, Paris 1876.- Schickendantz, Bul. de la Acad.
Nacional de ciencias in Cordoba I, 1874, 240.-
Tietze, Jahrb. der K. K. Ceolog. Reichsanst., 1877.-
Napp, Die Argent. Republ. Buenos Aires, 1876.-
Treitz, Földtani Közlöny, 38, 1908. S. 107.
4 Boussingault, Comptes rendus, T. LXXVIII, 1874, 453.
5 C. Klein, Sitzungsbericht, K. Preuss. Akad. der Wissensch. 1901, 612, 613.
Bertainchaud, Comptes rendus, CXXXII, 1001.
E. Clerici, Bull. Soc. Geolog. Ital. 20, CLXIX-CLXXIX.
Dimo, Agricultural Gazette for Southeastern Russia, 1911, 1-3 (Russian)

parent rocks. Where the accumulation is present in but one of them however its presence is presumably due to differences in the parent rocks. For example the Tschernosem of the high plateau of Transcaucasia differs from the corresponding type of European Russia in having an unbroken lime carbonate horizon. In the former soil the larger amount of lime carbonate is explained by the much higher percentage of that material in the parent rock than in the parent rock beneath the Tschernosem of European Russia.

Soil building and atmospheric processes produce, in every climatic zone more or less salts, but their accumulation in soil can take place only where the rainfall is light and the total evaporation is large.[1] In such regions the salts accumulate mainly in lower lying localities into which they are carried by surface waters or are brought up from the shallow ground water.

We will describe first the alkali soils and the composition of their salts found in America and Western Europe, basing it on their literature and then take up the description of Russian localities.

In Europe alkali soils are found in the Spanish peninsula, in New Castile and Aragon. Their most important occurrence have been shown by Ramann[2] on his soil map. The soils are developed on desert steppes. Such soils occur in southern France also. Recently they have been described from Hungary by Sigmond[3] and more fully by Treitz[4]. The first of these authors divides these soils into two main groups with subordinate groups:

I. Soda-bearing soils.

a. Soda-bearing soils with low content of water-soluble salts.
b. Soda-bearing soils with water-soluble salts.

II. True alkali soils, grouped according to texture into sandy, loamy and clay soils.

The soils of the first group occupy, for the most part, the higher lying localities, occurring very rarely in depressions and are characterized by a low percentage of salts and of soda. Sigmond describes them as follows: "The upper horizon, containing varying amounts of organic matter is grayish or black according to the amount of such matter present. Beneath this lies a black or brown pitch-like pasty sectile clay layer with a slick or smooth feel. Beneath this is a third horizon consisting of a clayey or

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1 Under the influence of other climatic conditions salts can accumulate in small quantities only where there is no outlet for surface or ground water.
2 Ramann. Pedologie, 1902, I.
3 Sigmond, Földtani Közlöny, 1906, Okt.-Dec. S. 439-454.
4 P. Treitz, Földtani Közlöny, 1908, S. 106-131.

sandy marl containing innumerable lime carbonate concretions, similar to the so-called loess kindchen." The sodium compounds soluble in water consist mainly of glaubers salts. Chlorides are present in small quantities only and sodium carbonate is present in places. In the soils of the region in which these alkali soils are found there is a content of soluble salts ranging from 0 to .5% of which 0 to 2% is soda. These figures apply apparently to the surface soil horizon.

The soils of the second group, the true alkali soils, are found between the Danube and the Theiss and occur distributed over the whole country including the deepest depressions. Sigmond is of the opinion that the salts of these soils are like those of the neighboring bodies of water, from which the soil received the previously formed soda. Only a part of the latter appears in the soil as a product of the reaction of NaCl on $CaCO_3$ in the presence of free carbonic acid in the soil atmosphere. On the surface of these soils true salt crusts or efflorescences of salts are found. It is characteristic that these soils are rich in $CaCO_3$ reaching a percentage ranging from 16 to 37. The highest percentage of soluble salts determined by Sigmond was 2 to 2.5, of which half, occasionally more, was sodium carbonate and the rest, NaCl. Glaubers salts did not occur in important quantities.

Treitz who investigated the alkali soils of the great Alföld distinguished several varieties:

"Soda or Szek soils, which are found in various portions of the great Alföld have a widely varying appearance. Their characteristics, color and relationships vary a great deal. On careful examination however, it soon becomes clear that all these forms merely represent different stages in the operation of the same process, the development of a soil under the influence of carbonate of soda, from a meadowland clay or loam soil". Treitz separated the soils, according to the topography of their occurrence into two groups:

(1) Valley soda soils and (2) Plateau soda soils. In each several varieties may be found. Alkali soils which are predominant in the deep depressions occupy a subordinate position on the plateau.

"The rain water", says Treitz in his description of the Valley soda soils, "dissolves the humus compounds soluble in alkaline water, the color of the soil becomes progressively lighter, until at last there is hardly any humus left. The surface color becomes gray and the surface bare. This variety of the soda soil is known as Gray Szek. The black solution dissolved from what is now the gray soil flows into the adjoining depressions where it may accumulate as a 50 to 100 cm layer of the most highly humus clay." The surface does not remain black however, it is leached and forms a 5 to 10 mm layer or crust consisting of a fine grained skeleton soil.

We cannot take up in this place all the interesting characteristics of the relief of the alkali soil region described by Treitz. For details we refer the reader to Treitz's original works. Nothing more than the observation of the author concerning the changes in composition of the salts of the various horizons at various times of the year will be taken up here.

"During the rainy season" says Treitz, "the sodium carbonate in solution in the soil moisture percolates through the surface layers of the soil and into the deeper horizons suffering transformation into sodium sulphate by reaction with the crystalline gypsum present in the latter. On the return however of the warm season it rises with the soil moisture reaching the place where the gypsum has been changed through reaction with carbonic acid to lime carbonate and through the action of the latter the sodium sulphate is changed through reaction to sodium carbonate and as such it rises to the surface". The presence of soda is extremely characteristic because in this region it is not only found in the soil but in all salt lakes also. For Hungary, Treitz gives the following data:

Composition of the waters of some of the salt-lakes in the region between the Danube and the Theiss, Komitat Pest and Bacs[1]

	Grams per liter			
	Na_2CO_3	NaCl	Residue on drying	SO_3
Ivanacska near Zombor	3.4476	0.9536	6.52	0.789
Fehermocsar " "	2.1746	0.3978	2.84	-
Kerektó near Bajsa	1.696	0.7546	3.76	-
Deveny near Gyurgyevó	3.6598	1.3572	6.38	1.133
Kopovo near Zsablya	0.5039	0.3276	1.36	-
Ruszanda near Melencze	1.976	1.893	6.276	2.040
Halasto near Halas	0.9285	0.1895	1.14	-

[1] Petrovits Döme, Zomborvedéki mocsarakrol. Term-tud. Közlöny, XV, 1898.

In North America alkali soils are found mainly in the semi-arid region of the Rocky Mountains and in California.[1] In the former they are known to occur in Colorado, Montana, Utah, Oregon and Washington. In California where the rainfall increases toward the north the southern part of the state is especially rich in alkali soils. The northern limit of the occurrence of injurious amounts of alkali lies north of Sacramento. The rainfall is only about 12 in. The springs lying both north and south of this place contain water unfit for drinking purposes because of the high content of Epsom and Glauber's salts. The water in the brooks is poor also. The dryest region is the plateau between the Cascades and the eastern part of the Rockies. The region richest in salts is the "Great Bend Country" where the soil is completely covered with efflorescence.

Of all the American investigators Hilgard interested himself most in the alkali soil problem. The following tables are taken from his work. They give us a comprehensive exhibition of the composition of the salts in various salt-bearing soils throughout the world. The figures in the tables give the percentages of the total salt content of the soil made up of each constituent. (See pp.194-5)

From this data it is seen that the salts present in alkali soils vary greatly in their composition but NaCl, Na_2SO_4 (and $NaHCO_3$) predominate. In part these salts are mutually exclusive. When the soda ($NaCO_3$) is abundant Na_2SO_4 and NaCl do not occur at all or in small amounts and vice versa.

The American investigators divide alkali soils into two groups, those with white alkali in which various salts like NaCl, Na_2SO_4, $CaCl_2$, $MgCl_2$, occasionally borates and nitrates, are present, and those with black alkali in which soda predominates.

Hilgard was the first investigator to note the occurrence and recognize the importance of soda in alkali soils. Its presence was noticed later by Giordiagin[2], Kossowitsch[3], and others. The reactions of the soda-forming processes in the soil were described by Rudolf Brandes in 1826. Alexander Müller, improved the description of the processes in 1855, and finally by the investigations of

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1 This can be accepted only as a very broad statement. Its occurrence is much more abundant in the Great Basin and certain parts of the Great Plains than in the mountains. CFM.

2 Giordiagin, Arb. der Naturforsch. -Gesellsch. der Kazan- Universitat. T. XXXIV, 1900; Verhandl. der Westsibir. Abt. der Kais. Russ. Geogr. Gesellsch. H. XXII, 1897.

3 Kossowitsch, Bericht der landw-chem. Laborat. des Ackerbau-Minister, Lief I, S. 22, Lief III, S. 1-18-22; Journ. der Russ. Experiment Landwirtsch.1903, H. 1.

UNITED STATES OF AMERICA

	California									Washington			
	1	2	3	4	5	6	7	8	9	1	2	3	4
K_2SO_4	...	...	...	20.23	3.95	10.13	0.92	5.31	20.62	3.90	0.16	4.53	6.27
K_2CO_3	...	...	...	...	...	...	...	...	6.59	18.44	15.17	15.20	...
Na_2SO_4	4.67	13.00	46.12	...	25.28	88.42	43.34	66.78	...	...	...	...	...
$NaNO_3$	12.98	...	...	...	19.78	...	...	...	...	...	...	...	...
Na_2CO_3	75.95	52.22	34.30	65.73	32.58	0.42	15.38	15.85	62.22	75.61	80.35	77.10	87.14
NaCl	1.46	33.00	17.45	3.98	14.75	0.51	39.34	11.47	10.57	0.52	1.76	1.34	4.03
Na_2HPO_4	4.94	1.78	2.05	8.42	2.25	...	1.02	...	...	1.53	2.55	1.13	2.53
$MgSO_4$	...	...	...	1.65	...	0.52	...	0.59	...	...	...	...	...
$(NH_4)_2CO_3$	...	...	...	...	1.41	...	...	...	...	...	...	...	...

UTAH (SALT LAKE VALLEY)

	1	2	3	4	5	6	7	8	9	10	11	12
$NaCO_3$	...	0.96	9.28	...	trace	trace	trace	0.23	...	0.30	...	trace
$CaCl_2$	0.77	...	...	...	...	...	...	...	7.62	...	...	...
$MgCl_2$	0.38	...	...	10.41	...	...	6.21	...	10.37	...	4.77	...
$CaSO_4$	1.98	0.79	1.06	13.24	2.14	6.38	...	7.43	9.97	0.25	9.32	7.33
$MgSO_4$	...	0.25	0.37	3.16	0.12	29.87	0.75	22.61	...	0.71	2.64	32.32
Na_2SO_4	...	31.15	43.12	...	11.97	8.29	...	9.75	...	49.43	...	9.86
NaCl	96.9	66.84	46.17	73.18	85.94	55.48	89.31	59.98	72.04	49.30	83.26	54.49

	Europe		Asia					Africa			Australia	
	Hungary											
	Kaloska	Debreczen	Araks Valley			Aden	India	Egypt		Fezzan	Bendigo	
K_2SO_4	...	...	...	...	...	...	11.1	...	...	...	1.28	1.63
Na_2SO_4	0.2	1.6	10.4	18.9	15.5	...	7.0	23.6	38.3	0.6	40.05	...
Na_2CO_3	48.1	92.5	14.7	12.1	69.0	67.2	79.0	28.2	47.7	98.7	...	...
NaCl	51.7	4.4	7.6	69.7	15.5	32.8	2.9	43.2	14.0	0.7	47.47	81.88
Na_3PO_4	...	1.5	...	...	...	....	...	...	...	...	...	...
$MgSO_4$	...	...	...	...	...	...	...	...	...	...	11.20	9.86
$MgCl_2$	...	...	...	...	...	...	...	...	...	...	...	6.73

Hilgard[1] they were fully explained.[2] According to Hilgard the reaction is a reversible one consisting of the reaction of the carbonates of lime and magnesia on the chlorides and sulphates of the alkalies in the presence of an excess of carbon dioxide. Sodium carbonate and the chlorides and sulphates of lime and magnesia are formed. The reaction takes place more readily if the sulphates only are present since the gypsum that is formed is less soluble than calcium chloride. It crystallizes out of the solution and in this way prevents any reverse reaction.[3] A warm or hot climate is favorable to the formation of sodium carbonate, according to Hilgard very large amounts being formed only in regions with warm climate such as Egypt, North Africa, Arabia, Northwestern India, Turkestan, Mexico, etc.[4]

Hilgard secured a great deal of data concerning the distribution of salts in alkali soils by making and analyzing water extracts of samples taken at various depths. In making the boring for the sample resistance was met with at about 45 cm..from the surface; between 45 and 90 cm. the resistance was greatest and decreased rapidly below that, disappearing at about 120 cm. This phenomenon was caused by the presence of sodium carbonate at the various depths given. The depths mentioned have no general significance since they are determined by the depth to which the rain water can penetrate. The hard salt horizon holds back the percolating water for a long time. The amount of salt present up to a depth of 55 cm, does not reach more than 0.15% and at a depth of 17.5 cm. it is wholly unimportant. This is the depth to which the roots of annuals penetrate, going occasionally however as deep as 62 cm.

The relation to each other of the three sodium salts mentioned above is different in the upper horizons from what it is in the harder and deeper ones. Since these phenomena cannot be explained by the various solubilities of the salts, at least of the sulphates and carbonates, it is presumably due to the chemical reactions which take place and which will be discussed below.

On the maturity and death of the surface cover of vegetation the surface layer of the soil becomes very dry so that there can be no suggestion of a rise of the salt solutions to the upper layers.

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1 Hilgard, Origin value and reclamation of alkali lands. Yearbook of the U. S. Dept. of Agriculture, 1895, 103 - Hilgard. Ann. de la Science agron. franc. et etranger 1893.

2 The Russian chemists Milikow and Tanatar carried out special investigations concerned with the conditions under which sodium carbonate is formed in nature. See also: Schweinfurt and Lewin; Zeitschrift der Gesellsch. für Erdkunde zu Berlin, 1898, 33, Nr. 1, S. 1-35.

3 Blanckenhorn (Zeitsch. d. geol. Gesellsch. 1902, 53, H. 3) in describing alkali soils on the shores of an abandoned channel of the Nile gives a different reaction for the formation of sodium carbonate.

4 There is still another hypothesis concerning the formation of sodium carbonate which we shall describe when discussing the chemistry of the Russian alkali soils.

Leaving out of consideration the dry autumn season no efflorescence of salts takes place on the surface.

Colemore's investigations showed that in an area more or less circular in shape in which the percentage of salts is high the amount of sodium carbonate increased toward the center. The sodium chloride on the other hand and in a less well defined way the sodium sulphate also, decreased in amount toward the perimeter of the area.

A well defined distribution of the sodium carbonate with depth was found to exist. On the surface the sodium carbonate made up 22.7% of the total salts present. The percentage increased with depth and at the depth of a meter it reached 94. The highest percentage of all salts including the sodium carbonate was found at a depth of 75 to 83 cm.

From this data it is evident that the sodium carbonate forms mainly in the deeper horizons. If the salt solutions rise toward the surface a reverse reaction sets in and sodium sulphate and calcium carbonate are formed by reaction with gypsum and the sodium carbonate percentage decreases. Since this reaction acts slowly however it may take place in any horizon, depending upon the rate of rise and evaporation of the solution so that the calcium humate, formed by the reaction between the alkaline solution and humic acid, and which is precipitated as inclusions and intermediate layers at various depths must be looked upon as the result of this reaction.

Thus the American investigators on the basis of their observations ascribe the composition and distribution of the salts to temperature and moisture. But they are influenced also by the capillarity, degree of solubility and by the great variety of the crystal forms of the salts.

The maximum percentage of nitrate is found in the surface horizons and decreases uniformly to a depth of 60 cm. Below this depth only traces of it are found and in the indurated horizon it is absent entirely. It is an interesting fact that on evaporation of the water extract the nitrate of magnesia usually remains intact.

The following table shows the distribution of the salts in the soil profile of ten alkali soils from the Salt Lake Valley, Utah:-

Sample Number	Depth in centimeters							Depth to ground water surface
	30 cm	60 cm	90 cm	120 cm	150 cm	180 cm	210 cm	
1	0.07	0.07	0.08	0.09	0.10	0.07	...	3 m
2	0.05	0.05	0.06	0.07	0.07	...	...	...
3	0.58	0.23	0.19	0.19	0.14	0.18	...	30 cm
4	0.49	0.21	0.18	0.16	0.16	0.17	...	90 cm
5	0.58	0.41	0.24	0.15	0.16	0.16	...	90 cm
6	2.07	1.44	1.13	0.86	0.82	0.92	...	1m 35 cm
7	0.11	0.09	0.23	0.54	0.88	0.81	0.67	1m 65 cm
8	0.38	0.95	1.17	1.38	2.04	2.36	...	1m 80 cm
9	0.74	1.38	1.65	2.09	2.09	2.21	...	1m 65 cm
10	1.43	2.37	2.60	3.66	3.66	3.37	...	1m 80 cm

South America also is rich in alkali soils. They are known to occur in the Campos of Brazil, the Pampas of Argentina and Patagonia, and on the deserts of the high plateau of Peru and Chili. According to Stelzner[1] salt crusts and efflorescences are formed during the dry season (April to September) when the loess soils of the Pampas are bare or covered only with a sparse vegetation. The crusts may attain a thickness of a few millimeters. Areas covering square miles in extent glisten as though covered with snow. Such areas lie in faint depressions so shallow that their basin shape is imperceptible to the eye. To the observer they seem perfectly flat and it is only by means of the increasing amount of salts that the traveler is able to recognize the lowest parts of the depressions. Along with the increasing percentage of salts the trees and brush decrease in number and vigor. This is true even of the trees and brush growing only on alkali land, so that in the vicinity of the lowest areas of the depressions they disappear entirely. The typical characteristic of true alkali soils is their absolute barrenness. Toward the rims of the salt bearing depressions the sulphate and chloride of sodium predominate as they do in the center. Stelzner found no sodium carbonate, though DeMoussy referred to its presence in 1860. (See the table following). Chloride of calcium[2] was found in places also.

1 Stelzner, Beitrage zur Geologie and Palaeontologie der Argentinischen Republic, T. 8. 1885.

2 The presence of chloride of calcium ($CaCl_2$) is indicated in alkali soils by black spots.

In the soil crust the percentage of salt ranges usually between 2 and 4 but the crystalline powder which may often be seen as an efflorescence may contain 80 per cent or more of salts.

The following table gives the composition of some alkali soils from Argentina:

	I %	II %	III %	IV %	V %
$CaSO_4$	8.09	3.59	0.75	11.23	9.41
K_2SO_4	...	4.04	0.84	14.19	10.41
Na_2SO_4	...	...	18.59	26.52	10.57
$MgCl_2$	...	0.67	...	...	...
KCl	2.40	...		...	...
NaCl	88.82	91.70	79.59	47.07	68.54
$MgSO_4$	0.69	...	0.23	0.99	1.08

Alkali soils are known to occur in Asiatic Russia, China, Bokhara, the Arabian Peninsula, Persia, Asia Minor, in the deserts and desert Steppes of Manchuria, Chinese Turkestan and Hindustan. In India they are known by the natives as "Reh". On the shores of the Arabian Sea and on the Indus they cover a large area, stretching from the latter to the Ganges. From the Gulf of Cutch they extend into the interior as far as Afghanistan. Hilgard inferred that the alkali soils in northwestern India had accumulated because of the characteristic distribution of the rainfall through the year rather than because of the small amount, since the region receives a considerable rainfall (about 28 in.). With the exception of November the monthly rainfall is low and for that reason the soil does not receive at any one time sufficient rainfall to wash out of it the soluble salts. The alkali soils of India are very rich in carbonate of lime, a continuous layer of lime tuff known as kankar lying in places at various depths.

In Africa the Sahara and its northern boundary regions are rich in alkali soils. They are found in the deserts and semi-arid regions of southern Africa also. They are known to occur in central Australia.

We will turn now to the consideration of the morphology and chemistry of the alkali soils of European and Asiatic Russia which have been extensively studied in recent years by the various expeditions sent out by the Emigration Office.

As has been mentioned above the Russians divide alkali soils into two groups: Alkali soils with definite structure or "Solonetz" and alkali soils without structure or "Solontschak." Both kinds are found in typical development in the Tschernosem region while the zones of Chestnut Colored, Brown and Gray soils are still richer in them. In the Brown soil zone large areas are covered with such soils, the greater part of which are Solonetz-like in character.

ALKALI SOILS WITH STRUCTURE

In the profile of these soils two humus horizons may be easily recognized: The Elluvial or upper or A horizon and the illuvial or lower or B horizon. Horizon A is more loose and somewhat light in color while horizon B is darker and more compact.[1]

The structure of the A horizon varies. It may be laminated or cellular[2] with round or oval cavities, 1 to 2 mm. in diameter, or it it may be granular or, again, without definite structure of any kind. Its thickness is variable also ranging from a few millimeters to 20 cm. or more. In the varieties with an especially thick horizon A its various parts may differ in composition and characteristics, a fact that justified the division of the whole horizon into a number of subhorizons (A_0, A_1, A_2). As a rule the upper part of horizon A is darker than the lower.

The profile of the B horizon is also variable, so much so that these soils may be grouped into columner, prismatic and lumpy varieties.[3] In the columnar soils the upper part of the B horizon is made up of distinct columnar bodies 3 to 8 cm. broad. Toward the upper end they become narrower and terminate in Keg-shaped and rounded forms which do not touch one another. These and the lateral surfaces of the columns are covered with a whitish surface coating.[4]

In the prismatic varieties horizon B falls into prismatic parts sometimes with pencil shapes by vertical cracks from 3 to 6 cm. apart. The upper surfaces of these prisms are smooth and as in the columns above they are coated with a whitish material.

In the lumpy or cloddy varieties horizon B is broken up by irregular cracks into lumps and clods. Their surfaces are smooth and covered with a white coating.

In each of the varieties horizon A may have various structures thus producing a great number of soil varieties.

The color of the Solonetz soils corresponds in general with the color of the soils of the zone in which they occur so that we have Tschernosem Solonetz, Chestnut colored Solonetz, Brown Solonetz, etc.

The following two Solonetz profiles describe soils in the Turgaj and Akmolinsk region.

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1 Semjatschenski, Sketch of Pady, Estate of Naryschkin, 1894 (Russian)
Gordiagin, Work of the Natural History Society of the University of Kazan, 34, 1900 (Russian)

2 Gordejew, Arbeit. der Nat. Forsch. Gesell. zu Saratow, 5, 1905---- Tumin, Pedology, 1904 No. 3 (Russian)

3 Tumin, Work of the Expedition Organized for the Investigation of the Regions to be Colonized in Asiatic Russia. Soil Investigation, 1908, Part 10, 1910, (Russian)

4 Lewtschenko, Arb. der Bodenexpedition zur Erforsch. der zu Kolonisierenden Regionen des Asiatisch. Ruszlands. Bodenforsch. 1908. Lief 1. 1909.

I. Columnar Solonetz from west of Tschulak-saj.

Horizon A. Laminated, in the upper part distinctly so, in the lower visible only on close examination; color yellowish gray becoming whitish in the lower part. The whitish shade increases with depth and at a depth of 20 cm. it becomes ashlike in color; the ash-colored layer passes in its lower part into the yellowish gray lower horizon and stands out distinctly from Horizon B. No effervescence in acid takes place. Its average thickness is as follows:

$A = 25$ cm, of which $A_1 = 20$ cm and $A_2 = 5$ cm.

Horizon B. Characterized by vertical cracks breaking the horizon up into vertical columns 3 to 4 cm in diameter and 12 to 14 cm long. In the upper part the columns are inclined away from one another, in the lower part they lie against each other and occupy all the space. The upper part of each column is roundish and is covered with a whitish dust from horizon A_2. On breaking them up they fall into sharp edged wedge shaped bodies, resistant, with smooth glistening surfaces of fracture. The color of the horizon is brown, occurring as it does in the Chestnut Colored zone and its thickness is 15 to 16 cm. It does not effervesce in acid.

Horizon B_2. Compact, falls into irregular fragments on digging, a little lighter than the B horizon, spotted with lime-carbonate spots. It is 19 to 20 cm thick and effervesces vigorously in acid of medium strength.

C. Yellowish gray loam with a grayish shade. Lime carbonate accumulations, more abundant in the upper part, make it somewhat spotted. The whole mass effervesces in acid.

II. From the vicinity of Dengis lake in the Atbassar district of Akmolinsk[1] Prismatic Solonetz.

Horizon A. Grayish brown color, laminated. The various laminae differ but little in color. The horizon is loose and on crushing falls into dust. 8 cm.

B_1. Marked by a sharp boundary between A and B, dark brown in color, compact. On account of vertical cracks it is broken up into prisms from 3 to 5 cm in diameter. They are very compact and hard, so much so that they are difficult to crush. The fracture faces are conchoidal. The upper end of each prism in contact with A has a white coating. The transition to the underlying horizon is gradual.

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[1] Tumin, l.c.p. 27 (Russian)

Horizon B_2. Brown with a faint humus color; carries dark tongues and flecks consisting of small spots of salt secretions which do not effervesce in acid. 47 cm thick.

C. Light brown loam, contains imperfectly developed crystals and accumulations of salts which do not effervesce.

Immediately on the surface faint effervescence in acid will take place. In horizons A and B on the other hand no effervescence takes place, though B_2 and C will effervesce. If A and B are treated with acid and examined very closely a very faint effervescence may be noticed on the surfaces of the cracks.

The two profiles given above were described from localities in the southern part of the Chestnut Colored soil zone. Similar soils are found however in the Tschernosem and in the Brown and Gray soil zones of European and Asiatic Russia.

Solonetz-like Soils

In association with typical solonetz soils others occur in which the morphological characteristics are similar to the typical but faintly developed. Two kinds have been identified[1]; Solonetz-like soils and faintly developed solonetz-like soils. They may be found in all soil zones in which alkali soils are found, though the Brown[2] soil zone is especially rich in them. In the solonetz-like soils horizons A and B differ markedly in color and structure. Their contact surfaces are not smooth and the whitish coating is entirely absent. In the faintly developed solonetz-like soils the differences in color and structure between horizons A and B are unimportant and the transition from one to the other, because of this slight difference, is gradual.[3]

The following profile description applies to an occurrence in the valley of the Talagaj in the Atbassar district in Akmolinsk.[4]

Solonetz-like Soils

Horizon A. Light gray color, compact, containing fine pores. 1 cm thick.

B_1. A sharp boundary between this and horizon A. Dark brown, somewhat moist, falls into prismatic blocks with horizontal cleavage on being broken up. On crushing it falls into granular lumps. 4 cm. The transition to the underlying horizon is gradual.

Horizon B_2. A little lighter in color and less compact than the overlying horizon. Contains small accumulations of non-effervescing salts. At 15 to 20 cm in depth they become very numerous but at greater depths they become but faintly differentiated from the ground mass.

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1 Tumin, l. c. pp. 8-11. See also Stassiewitsch, Ibid. Bodenforschungen, 1909. Part 3, 1911 (Russian).

2 Dimo, Semiarid formations in the southern part of the Tsaritszin District. 1907, Saratow (Russian).

3 Tumin, l. c. pp. 10-11.

4 Tumin.

the amount decreases while crystals of salts occur and increase in number downward. 40 cm.

Horizon C. Chocolate-colored with inter-laminated layers of bluish clay. The chocolate colored layers carry abundant salt crystals.

The following profile description of faintly developed Solonetz-like soil refers to a locality from the vicinity of Dengis lake, Atbassar district, Akmolinsk.[1]

A. Chestnut colored. To a depth of 4 cm it has a laminated structure, is loose and falls easily into shot-like fragments. Does not effervesce in acid. Below 4 cm in depth however it effervesces in acid, is browner, and darker, compact, of very fine grain and on breaking falls into clods which show a tendency to horizontal cleavage and on crushing break up into granular lumpy particles. The transition to the succeeding horizon is rapid. 17 cm.

B. Somewhat browner and darker than the overlying horizon. The upper 5 cm of the horizon however are very much like the lower part of A in structure and color. If one examines the density or compactness of the profile horizon B is seen to be more compact than A. It falls into clods or prismatic fragments by breaking either along well marked or concealed lines of breakage. The fragments are especially compact in the lower part of the horizon and can be broken into fine particles with difficulty. The fractured faces of the clods break conchoidal in a horizontal direction, occasionally with a faintly glistening surface. It effervesces in hydrochloric acid. The transition to the underlying horizon is abrupt. 20 cm.

B_2. Lighter in color than B, compact, rich in lime segregations at 37 to 53 cm from the surface but at greater depth the number of the spots decreases and the compactness decreases.

C. Light brown loam with spots of a bluish clay. Contains small accumulations of salts that do not effervesce in acid. The mass of the horizon effervesces in acid however.

In horizon B of the solonetz-like soils the prismatic structure is developed as it is in the solonetz soils. The same varieties, based on differences in the surface or A horizon, may be found as in the solonetz soils.[2] The faintly developed

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1 Tumin, op cite.
2 Tumin, op cite.

Solonetz-like soils may be grouped into varieties on the basis of the structure of horizon A such as: laminated, compact, granular. In these soils horizon B is not developed to a sufficient extent to warrant a separation on that basis as is done in the Solonetz soils.

The depth of effervescence in the Solonetz-like and faintly-developed-Solonetz-like soils varies rather widely. Some exist which effervesce on the surface. Non-effervescing salts are either absent entirely from the humus layer or exist only in the lower part of B, occasionally however they rise to the surface horizons.

Like the Solonetz soils these soils differ in the color of the surface horizon, that being determined by the color of the zonal soil type in which they occur. Solonetz-like soils may have a Tschernosem, Chestnut, Brown or Gray color according to the zone in which they occur.

Solontschak Soils

Alkali soils in which the upper and lower humus horizons have the same development and are rich in soluble and sometimes rich in insoluble ($CaCO_3$) salts are called "Solontschak" soils. Like the Solonetz soils they are found in various soil zones and may be designated by prefixing the zonal name to the soil name. There are also various transition varieties between true Solontschak and true zonal soils such as Solontschak-like Tschernosem, Solontschak-like Chestnut Colored soil. Finally Solontschak soils may differ in the particular salt which predominates such as chloride, sulphate and carbonate varieties. In such cases they are designated by prefixing the name of the predominant salt to the zonal soil name. Carbonate Solontschak soils are confined to regions with considerable rainfall in which the more readily soluble salts have been dissolved out. They occur for example in the northern part of the Tschernosem zone where they may be considered as transition soils between the Solontschak soils of southern latitudes and the water logged soils of the Podsol zone. I have seen them myself in the Grubischow district of Lublin where they had a thick humus layer on the surface but which effervesced in acid. The subsoil was rich in marl and in places consisted of a loam with a hardpan-like layer of concretions. Polynow[1] described certain varieties of a similar soil from Tschernigow. A characteristic group of carbonate Solontschak soils was found on the Turkestan[2] slopes of the Altai Mountains, in places in Jenisseisk and everywhere on the mountain chains in the desert steppes.

All these soils have softer humus horizons than those of the associated zonal soils, but in certain other respects they resemble the latter. Another characteristic feature present only in the

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1 Polynow, Soils of Tschernigow, Part I Eastern Tschernigow, 1906, (Russian).

2 Prassolow, Work of the Expedition Organized for the Investigation of Land in Asiatic Russia to be Colonized. Soil Investigation, 1908. Pt. 5, 1909 (Russian).

Carbonate Solontschak soils of mountain regions is the high percentage of marl in the subsoil. In the transition from a mountain slope to a more even surface the carbonate rises and appears in the surface horizons in important quantities. Prassolow, in his investigation of the soils of the Tian Shan Mountains, designated such soils as White Earths or soils that had been bleached out. Rusty spots of hydrated iron oxide were often seen beneath the carbonate horizon in these soils. There are some facts which indicate that the hydrated iron oxide as well as the carbonate was precipitated during the rise of the ground water, found here but a few feet below the surface. At any rate the origin of the mountain Carbonate-Solontschak soils has a close connection with the mountain slopes and the downward percolation of the soil water.

Profiles of the Solontschak soils have been studied in many of the soil zones. The Carbonate Solontschak from Tschernigow in the northern part of the Tschernosem belt is described by Polynow[1] as follows:

"These soils lie in large and small depressions which are often flooded for short periods of time. They are covered with a thin stratified crust of efflorescent salts ranging from 3 to 5 mm in thickness. Beneath it lies a dark gray horizon A, 20 cm thick becoming darker with depth, very compact and hard, is very easily broken and on being struck falls into angular particles. Beneath it lies a soft plastic grayish brown transition layer of soil carrying prominent humus and white calcareous spots. This layer passes into the strongly marly, yellowish loam or into white marl. Effervescence in acid takes place throughout." Mountain-Solontschak soil from the right bank of the Koksa River is similar to the Tschernosem and according to Wolkow[2] has the following profile.

0-18 cm.	In the upper part it has a tough turf but deeper a well marked almost granular structure.
18-48 cm.	With less well defined structure, especially in the lower part. Lime carbonate secretions.
48-102	Lime carbonate segregations.

The soil of Jenisseisk, which in its habitat is like the Chestnut Colored soil[3], is very much like this. Its profile is as follows:

0-1.5 cm.	Loose, silty, full of roots.
1.5-9 cm.	A little more compact, without well marked structure, Chestnut brown color.
9-19 cm.	Lighter than the last, about the same in compactness, porous.

1 Polynow. Soils of Tschernigow. Part I. Eastern Tschernigow, 1906 (Russian).
2 Glinka, "La Pedologie" 1910, 4, p. 305.
3 Glinka, Idem.

19-44 cm. Still lighter in color, porous, becomes soft and plastic.

A bed of gravel lies at a depth of 66 cm and above it a light rose colored layer.

Chloride and sulphate Solontschak soil in the vicinity of the Dengis Lake in Akmolinsk[1] gives the following profile:

Horizon A_1. At top a 1 cm layer of light gray salt crust, which effervesces strongly in HCl. Below this lies a dark gray slightly compact horizon which has neither granular nor nut-like structure, effervesces weakly in acid and has no salt accumulation. The transition to the underlying horizon is gradual.

A_2. Brown with gray streaks and spots, similar in structure to horizon A and effervescing faintly in acid. Down to 30 cm the non-effervescing salt accumulations are abundant and small, while from 30 to 45 cm they are larger, and at still greater depths they become small and less well defined.

C Light brown, salt-bearing clay with few sandstone fragments. It effervesces strongly in acid. Contains spots and crystals of salts. The whole profile is moist, the substratum still more so. At a depth of 110 cm salt water is found.

The soft SO_3 and Cl-bearing Solontschak soil lying behind Karatau, 10 wersts south of Askumbe is described by Neustrujew[2] as follows: Soft Solontschak with salt efflorescences; beneath a thin gray porous 8 cm crust lies a loose brown salt-bearing mass and beneath it a brown lumpy moist horizon. Gypsum veins are numerous but they disappear at 70 to 80 cm. Beneath that the soil passes into moist brown clay containing a small percentage of gravel.

Solontschak and Solonetz form groups of soils which do not differ sharply one from the other; between the typically developed members there are many transitions. They may contain important quantities of chlorides and sulphates but have at the same time the morphological characteristics of the Solonetz soils. These characteristics are:[3] The occurrence of the upper crust forming horizon differentiating it from the underlying horizon characterized by a lighter color and a stratified or porous structure while

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1 Tumin, Work of the Soil Investigating Expedition to lands to be Colonized in Asiatic Russia. Soil Investigation, 1908, part 10, 1910, p 24 (Russian).

2 Neustrujew, Idem. Part 7, 1910.

3 Neustrujew, Idem. Part 7, 1910, page 215.

the third horizon is structureless[1]; the occurrence of a well developed horizon A along with that of a well developed, columnar horizon B.

The members of the Siberian Expeditions describe soils of this kind, and Dimo[2] has identified them in Saratow. According to the latter investigator the surface of the soil, in the vicinity of Sarepta on the Sarpa river, is covered, in midsummer, by a salt efflorescence several cm thick. Beneath that are laminated and columnar horizons in good development.

Now that we have become acquainted with the morphology of the alkali soils we will take up for discussion their analyses and follow with a discussion of their origin. In the analyses the characteristics of the various horizons of the Solonetz soils stand out markedly. The mechanical analyses of the A and B horizons of the columnar alkali soils of the Turgaj region, in the southern part of the Chestnut Colored zone, where it is passing over into Brown soils, is as follows[3]:

	Size of Particles								
Horizon & Depth in cm	3 to 1 mm	1 to 0.5 mm	0.5 to 0.25 mm	0.25 to 0.05 mm	0.05 to 0.01 mm	0.01 to 0.005 mm	0.005 to 0.0015 mm	Less than 0.0015 mm	Proportion of clay to sand
Soil #50									
A 0 to 20	0.317	0.260	8.067	43.039	12.265	20.223	6.936	7.378	1:1.9
B_1 20 to 37	0.052	0.064	4.425	39.169	9.917	18.228	11.715	15.825	1:1.2
Soil #54									
A 0 to 18	3.248	0.757	8.084	46.085	9.230	17.648	5.738	7.920	1:2.1
B 40 to 66	1.282	0.457	6.155	47.455	7.534	12.022	8.500	15.867	1:1.8

According to this therefore the compact hard horizon B is higher in fine grained silty material than is the loose Horizon A. The latter material has been carried from A to B. On this basis one can infer that the total analysis of the columnar Solonetz

1 See Abutjkow, Work of the Soil Expedition for the Investigation of the areas to be Colonized in Asiatic Russia. Soil Investigation, 1908, Part 3, p. 62 (Russian).
2 Dimo, The Semi-arid formations of the southern part of the Tsaritzin District. Saratow, 1907 (Russian).
3 Skalow. Work of Expeditions for the Investigation of those parts of Asiatic Russia to be Colonized. Soil Investigations 1909, Part 2, p. 66 (Russian).

soils will show marked differences of composition between these horizons. As a matter of fact horizon A, in the Solonetz soils of Jenisseisk[1], as will be shown below, is poorer in bases, especially of sesquioxides but richer in silica than is horizon B. One would obtain the same results if the fine particles of A were mechanically mixed with horizon B, but it appears that in this case the transport from one horizon to another takes place not merely mechanically but chemically also.

Depth in cm	CO_2	Water at 105 C°	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	N	Total
A_1(0 to 3 cm)	...	1.09	9.29	66.48	11.98	3.87	1.57	0.99	2.35	2.46	0.070	99.27
A_2(15 to 21 cm)	...	1.11	3.42	71.89	12.01	3.79	2.29	0.31	2.29	2.58	0.096	98.706
B_1(21 to 29 cm)	...	2.72	5.37	66.36	14.76	4.71	2.89	0.74	2.60	1.98	0.066	99.496
B_2(32 to 41 cm)	0.58	2.00	7.86	62.04	15.48	5.23	3.25	0.28	2.42	2.77	0.114	99.518

After computation on a moisture and organic matter free basis, the results are:

	CO_2	Water at 100°C	Loss on ignition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	N	Total
A_1(0 to 3 cm)	...	...	....	73.29	13.21	4.27	1.73	1.09	2.59	2.71	...	....
A_2(15 to 21 cm)	...	...	....	74.43	12.44	3.92	2.37	0.32	2.37	2.67	...	....
B_1(21 to 29 cm)	...	...	....	70.12	15.60	4.98	3.05	0.78	2.75	2.09	...	....
B_2(32 to 41 cm)	...	...	....	68.31	17.05	5.76	2.76	0.31	2.66	3.05	...	....

The above conclusion is supported by the following analysis of hydrochloric acid extracts[2]:

1 Stassiewitsch, Work of the Soil Investigation Expedition for Investigating the Regions to be Colonized in Asiatic Russia. Soil Investigation, 1910, part 3, p. 77 (Russian.)

2 Skalow. Work of Soil Investigating Expedition, etc. 1910, part 3, p. 61 (Russian).

Horizons and Depth in cm	SiO_2	Al_2O_3	Fe_2O_3	Mn_3O_4	CaO	MgO	K_2O	Na_2O	P_2O_5	SO_3
A(0 to 12)	0.13	1.52	3.00	0.19	0.41	1.03	0.22	0.09	0.03	0.11
B_1(12 to 30)	0.18	6.71	4.73	1.59	0.65	2.04	0.45	0.34	0.09	0.09
C(98 to 108)	0.15	4.88	3.72	0.19	4.86	1.05	0.53	0.43	0.06	0.23

The increases in the amount of clay and of bases in horizon B cannot be explained as the result of mechanical translocation nor can the accumulation of Mn_3O_4[1] be so explained. In some varieties of alkali soils bodies very much like hardpan concretions, which can originate only from pseudo solutions, have been noticed.[2]

Because of the removal of a part of the fine-grained portion of this horizon it has a lower amount of moisture and chemically combined water. For example horizon A of the Solonetz soils from the Turgaj region contains 1.2 to 1.5% of moisture, while horizon B contains 3.35 to 4.95%. The following table shows the combined water in the same soils.

Horizons	A_1	A_2	B_1	B_2	C	C
Depth in cm	0 to 3	3 to 12	12 to 30	30 to 47	47 to 96	96 to 108
Combined water in %	0.82	0.57	3.17	3.86	2.49	2.45

The humus content of the Solonetz soils as well as its solubility varies with the horizons. The following table gives the results of an examination of Solonetz soils from the Tschernosem zone in Saratow[3]:.

[1] Skalow, Work of Soil Investigation Expedition, etc. 1910, part 3, p. 62 (Russian).

[2] These occurrences in alkali soils have not yet been fully investigated. It is possible that in many cases the concretions are a product of the degradation of the alkali soils beneath forests. Such occurrences have been observed in the Pawlograd district of Ssemipalatinsk.

[3] Dimo, Semi-Arid formations of the southern part of the Tsaritzin District Saratow, 1907, p. 195 (Russian).

Horizon and depth in cm	Humus %	Loss on ignition %	Relative humus content %	Solubility of the humus	Proportion of soluble to total humus
A 1 to 4	11.093	18.471	100	0.0287	1:306
A_2 4 to 7	6.118	11.838	55	0.0780	1:77
B_1 7 to 13	6.332	16.198	57	0.1704	1:37
B_1 15 to 22	6.439	16.460	58	0.2739	1:24
B_2 29 to 35	3.539	13.107	32	0.0348	1:101
B_2 42 to 50	2.905	11.826	26	0.0439	1:66
C 55 to 60	2.171	8.667	20	0.0316	1:69
C 65 to 70	1.928	8.594	17.5	...	...
C 75 to 80	1.030	7.522	10	0.0221	1.47

The results of an examination of a Chestnut Colored Solonetz from Jenisseisk, from the hilly steppes on the left bank of the Abakan are shown in the following table[1]:

Horizons and Depth in cm	Humus %	Loss on Ignition %	Horizons and Depth in cm	Humus %	Loss on Ignition %
A 0 to 3	4.25	5.56	B_1(21 to 29)	2.31	3.18
A_2 15 to 21	1.04	1.81	B_2(32 to 41)	1.22	2.43

A brown Solonetz soil from Saratow gave the following:[2]

1 Stassiewitsch, Work of the Soil Investigation Expedition etc. Soil Investigations, 1909, Part 3. (Russian).

2 Dimo. Ibid. pp. 193 - 206.

Horizons and depth in cm	Humus %	Loss on Ignition %	Relative humus content %	Solubility of the humus %	Proportion of soluble to total humus.
A_1 0 to 5	3.295	6.774	100	0.0183	1:180
A_2 5 to 8	1.666	3.495	50.5	0.0186	1:63
B_1 9 to 15	1.732	10.700	52.2	0.0456	1:40
B_2 20 to 25	1.334	7.897	41.7	0.0231	1:57
C 30 to 35	0.752	6.865	23.5	0.0217	1:35

A brown Solonetz from the Akmolinsk region gave the following results[1]:

Horizons and depth in cm.	Humus %	Loss on Ignition %
A_0 0 to 3	2.51	4.00
A_1 3 to 7	1.54	2.90
A_2 8 to 12	1.00	2.58
B_1 13 to 22	1.47	5.05
B_2 39 to 46	1.66	4.62
C 65 to 70	...	11.33[2]

The preceding tables show that the maximum amount of humus lies in the upper part of horizon A. In A_2 it is much less, the decrease corresponding to the increase in the lightness of the horizon color in nature. In Horizon B the amount increases somewhat and then decreases with the depth. It is difficult to say whether the greater humus content in B depends on an actual increase in amount or whether this process is apparent only, for the humus of A_2 is lower in its content of carbon than is that of B_1. It is certain however that the whitish material in A_2 belongs to the humus, for on the ignition of samples from this horizon the material becomes black at first, due to carbonization and is then decomposed.

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1 Stassiewitsch, Soil Investigation 1908, Part 2, p 26.(Russian).

2 This figure includes the CO_2 from $CaCO_3$.

A characteristic feature of Solonetz soils is the increase in solubility of the humus[1] with depth, especially in horizon B. In order to understand this phenomenon the following analyses of water extracts of various columnar Solonetz soils are given.

1. Solonetz from the Tschernosem zone of Saratow.[2]

Horizon and depth in cm.	Total soluble matter	Loss on ignition	Total of dissolved mineral matter	Cl	CO_2	SO_3	SiO_2	Al_2O_3	Fe_2O_3
A_1 1 to 4	0.0912	0.0369	0.0542	0.0017	0.0041	0.0170	0.0062	0.0046	0.0043
A_2 4 to 7	0.1235	0.0617	0.0618	0.0008	0.0065	0.0195	0.0056	0.0073	0.0054
B_1 7 to 13	0.3668	0.1574	0.2094	0.0024	0.0026	0.0531	0.0073	0.0043	0.0049
B_1 15 to 22	0.6458	0.1932	0.4526	0.0013	0.0067	0.2362	0.0084	0.0036	0.0021
B_2 29 to 35	2.8085	0.2284	2.5801	0.0004	0.0067	1.5459	0.0009	0.0011	0.0009
B_2 42 to 50	1.0478	0.0582	0.9896	0.0006	0.0353	0.5275	0.0012	0.0003	0.0015
C 55 to 60	0.8540	0.0316	0.8224	0.0009	0.0341	0.4307	0.0026	....	trace
C 75 to 80	0.5408	0.0180	0.5228	0.0009	0.0494	0.2359	0.0026	0.0009	0.0013
C 125 to 130	0.1754	0.0170	0.1594	trace	0.0523	0.0180	0.0016	0.0007	0.0008

[1] Dimo. Ibid.
[2] Dimo. Ibid.

CaO	MgO	K_2O	Na_2O	Reaction with litmus and color.
0.0067	0.0040	0.0036	0.0154	Almost neutral, faintly alkaline, golden yellow.
0.0049	0.0016	0.0053	0.0300	Same reaction; brownish yellow similar to strong tea.
0.0056	0.0052	0.0071	0.0740	Similar reaction; coffee color, semi-transparent.
0.0073	0.0063	0.0021	0.2010	The same as above, but darker.
0.3104	0.1184	0.0166	0.7235	Very faintly alkaline, golden yellow.
0.0059	0.0195	0.0131	0.4078	All strongly alkaline; all faintly yellow, almost colorless.
0.0057	0.0042	0.0636	0.3056	
0.0035	0.0017	0.0134	0.2256	
0.0010	0.0006	0.0043	0.0840	

2. Chestnut Colored Solonetz from Jenisseisk.[1]

Horizon and depth in cm.	Color of the water extract	General alkalinity (HCO_3)	Alkalinity of the alkalies	Alkalinity of the alkaline earths	Total amount of soluble material	Loss on igni- tion	Mineral Residue	Cl	SO_3
A_1 (0 to 3)	yellow	0.0264	0.0144	0.0120	0.0756	0.0432	0.0324	0.0012	0.0050
A_2 (15 to 21)	brown-yellow	0.0240	0.0154	0.0086	0.0872	0.0430	0.0442	0.0082	trace
B_1 (21 to 29)	brownish-red	0.0840	0.0768	0.0072	0.2412	0.1056	0.1356	0.0196	0.0072
B_2 (32 to 41)	brown-yellow-red	0.0932	0.0893	0.0039	0.2840	0.0580	0.2260	0.0290	0.0499

[1] Stassiewitsch, Work of the Soil Investigation Expedition etc. Soil Investigation 1909, part 3.

3. Columnar Solonetz from the transition belt between the Chestnut Colored and the Brown Earth zones, Turgaj region[1]:

Horizon and depth in cm.	Color of the water extract.	Total amount of soluble matter	Loss on ignition	Mineral residue	Alkalinity as Na_2CO_3	Cl	SO_3
A (0 to 3)	white opalescent	0.0441	0.0152	0.0289	0.0221	0.0008	0.00902
A_2(3 to 12)	same	0.0657	0.0215	0.0442	0.0170	0.0010	0.0075
B_1(12to30)	intense golden yellow	0.2362	0.0531	0.1831	0.0562	0.0649	0.0154
B_2(30to47)	golden yellow	0.5480	0.1610	0.3870	0.0500	0.2106	0.0616
C (47to66)	faint golden yellow	0.9560	0.1640	0.7920	0.0184	0.2254	0.2690
C (66to88)	pale yellowish	0.6380	0.0850	0.5530	0.0255	0.2242	0.1000

4. Columnar Solonetz from the same zone of the Akmolinsk region[2]:

A (0 to 3)	yellow	0.1000	0.0232	0.0788	0.0446[3]	0.0128	0.0102x
B_1(3 to 10)	darker than the preceding	0.2124	0.0448	0.1676	0.1354	0.0224	0.0066xx
B_2(36to41)	faint yellow	1.9898	0.0536	1.9362	0.0481	0.4288	0.5524xxx

x filters easily
xx filters slowly
xxx filters easily

[1] Skalow, Work of the Soil Investigating Expedt. etc. Soil Investigations 1909, Part 2, pp. 64-65 (Russian).

[2] Tumin, Same, Soil Investigations 1908, part 10 p. 47 (Russian).

[3] The Alkalinity is calculated as 2(HCO_3).

5. Columnar Solonetz from the Brown Earth zone of the Akmolinsk region [1]:

Horizon and depth in cm	Color of the water extract.	Total amount of soluble matter	Loss on ignition	Mineral residue	Alkalinity as Na_2CO_3	Cl	SO_3
A (0 to 3)	bright yellow	0.042	0.014	0.028	0.024[2]	trace	0.021
A_2(5 to 10)	" "	0.068	0.035	0.033	0.026	"	0.026
B_1(10 to 18)	" "	0.175	0.051	0.124	0.046	0.070	0.027
B_2(25 to 32)	almost colorless	0.451	0.059	0.392	0.036	0.094	0.035
C (53to57)	colorless	0.571	0.042	0.529	0.032	0.119	0.065

We could give a great many more analyses similar to those just given but these suffice to characterize the columnar Solonetz soils. The water extract always reacts alkaline, not only because of the presence of bicarbonates but also because of the presence of normal carbonates[3].

In this way they differ from the other soil types of the dry climatic zones. The normal carbonates are usually characteristic of horizon B of the columnar alkali soils.

The greater part of the analytical data were obtained from samples that were collected in summer. Since some of the authors[4] were of the opinion that horizon A of the Solonetz soils was de veloped, like that of the Podsol soils, in an acid medium which was present during the periodic flooding, it was necessary to determine how the soil reacted in spring time, when it was saturated w

[1] Stassiewitsch, Ibid. Soil investigations, 1908, part 2, p. 27.
[2] The alkalinity is calculated as $NaHCO_3$.
[3] It should be noted that the alkalinity of the normal carbonates may be determined with the use of phenolphthaleins but the alkalinity may be caused not only by the presence of alkaline carbonates, mainly Na_2CO_3, but also by the salts of the organic acids and silicic acid. See Gedrojtz, Methods of Chemical Investigation which are used in the Laboratory at St. Petersburg, St. Petersburg, 1909. p. 30 (German).
[4] Dimo. Semi-arid formations in the southern part of the Tsaritzin District, Saratow, 1907. (Russian).

with moisture. In order to determine this I requested Mr. Skalow to make the necessary test in the steppes of Orenburg in the early spring. His results are as follows:[1]

Soil Number	Horizon	Alkalinity in CO_2	Hygroscopic moisture
1	A_1	0.0122	17.856
2	A_2	0.0358	21.460
2	A	0.0176	19.107
3	A	0.0244	21.511
4	A_1	0.0217	22.807

All determinations were made on the water soaked surface horizon of the alkali soils all of which gave an alkaline reaction. This points strongly to the formation of Solonetz soils in an alkaline reaction. They have nothing in common therefore with the Podsols.

The highest alkalinity of Solonetz soils is found in the B horizon, whose water extract is usually darker than that of the other horizons and at times it is entirely black. This is the case with Solonetz soils from the Tschernosem zone.

The investigations of Hilgard and the Hungarian investigators concerning the presence of soda and the processes by which it is formed in Solonetz soils has already been mentioned (Page). There are however, other explanations of soda formation which were not touched on by Hilgard.

A comparison of the water extract of various alkali soils shows that the amount of humus in Solonetz soils has a definite relation to their alkalinity and the intensity of the color of the water extract. As a rule Solonetz soils high in humus react more strongly alkaline and the water extract has a stronger color. For this reason it may be inferred that the soda is formed in part because of the decomposition of the humus and the richer a Solonetz soil is in humus, the richer it will be in soda. Solonetz soils high in their content of humus are found in the southern soil zones and not confined exclusively to the Tschernosem zone. Yet these alkali soils are dark in color and are found, according to Tumin[2], only in certain localities, such as the upper part of river valleys where meadow lands border on the steppes.

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[1] This data was sent me in a personal letter by Mr. Skalow. This is the first time it has been published.

[2] See: Preliminary report of the Organization and Progress in the Investigation of the Soils of Asiatic Russia in 1910. St. Petersburg, 1911, page 89 (Russian).

The greater part of the sodium of the alkali soils is in the form of bicarbonate ($NaHCO_3$) but this compound does not change the humic acid into the sol condition. In the Solonetz soils however it is naturally in this condition. Only normal soda (Na_2CO_3) can effect the change, so that conditions must exist in Solonetz soils that are favorable to the formation of this salt. Treitz expresses the opinion that it is formed in the surface soil horizon through the influence of the sun's heat. The carbonic acid gas developed in horizon A forms pores.

Let us consider what takes place in a soil when its surface horizon is subjected to the process which forms the normal soda solution. First of all the humic acid passes from the Gel to the Sol condition and forms a pseudo solution[1]. In the latter the finest soil particles may be suspended since they have the characteristics of negative colloids. In addition to the humic acid, various mineral substances may pass into the pseudo solution for the basic humic acid "sols" constitute an energetic chemical reagent. The complex suspensions formed in this way will percolate into the soil. The following experiment carried out by myself will show what changes take place after this: A glass tube, the lower end of which was covered with fine material was filled with finely pulverized Tschernosem soil containing no chloride or sulphate. In to the upper end of the tube was poured solutions of $NaHCO_3$ and Na_2CO_3. The $NaHCO_3$ went easily through the tube without being held back, having received a faint yellowish coloration. The Na_2CO_3 solution changed the humic acid very rapidly into the Sol condition, the pseudo-solution thus formed reached only a shallow depth in which there followed the separation of gel. After a sufficient time had elapsed a dark ring was formed and the moist soil column would not allow any further solution to pass through. In the solution which had passed through the whole soil column no trace of normal sodium carbonate was to be found, only the bicarbonate of lime and soda being found, though no test was made for the presence of magnesia. This experiment shows that the solution of normal carbonate changes to the bicarbonate form at shallow depth as it percolates through the soil. In this form it cannot take up the humic acid in the Sol condition. The latter separates out in the gel form which holds back the very fine soil particles which have been carried in suspension from the higher soil horizon. If the pseudo-solution is rich in alkalies or other mineral matter concretionary precipitation may take place in this layer.

In this way the leaching of the surface soil and the formation of a tough plastic gel and suspension horizon is effected through the action of a normal soda solution. The process proceeds through the absence of chlorides and sulphates. An experiment shows that the solutions, rising to the surface from below contain no normal soda, but $NaHCO_3$ only. The solution of $NaHCO_3$ can rise to the

[1] It is possible that true solution takes place, in this case, also. See Sven Oden, Ueber die Natur der Humussäure. Arkiv. för Kemi Mineralogie och Geologie, utgifvet of K. Svenska Vetenskapsakad; Stockholm, 1912, 4 No. 26.

surface without effecting any essential change in the soil horizons through which it passes.

The chlorides and sulphates must bring about the coagulation of the colloids through their action as electrolytes. If they are present in a Solonetz their influence must become effective. Any salt effects coagulation however only when the amount of the salt in the solution has reached a definite concentration.[1]

It follows therefore that the change of the humic acid into the sol condition and its separation out in the gel condition is dependent on the relative concentration present in the soil horizons of the sol forming soda and the gel forming electrolytes. The formation of Solonetz soils therefore will take place if a small amount of soda be present and chlorides and sulphates are absent[2], if considerable amounts of soda and small amounts of chlorides and sulphates are present and finally if large amounts of soda and considerable amounts of electrolytes are present. On the other hand the amounts of sol former and gel former may be so related one to the other that Solontschak soils will be formed rather than the Solonetz.

From a great number of analyses and observations in the field it is evident that the typical profile of the Solonetz soils vanishes as soon as chlorides and sulphates rise to the higher horizons. In horizon B of the so-called crusted alkali soils; that is, those in which horizon A is very thin and often becomes merely a surface crust, there are important amounts of chlorides and sulphates which rise more strongly and abundantly to the surface than is the case in the so-called deep columnar alkali soils or in those with a thick leached horizon A. That is shown in part by the figures given on a previous page (217) showing the water extract of soil No. 5. In this case horizon B_2 contains almost 1% Cl and SO_3. The same thing is shown by the water extract of two crust-alkali soils from the Turgaj region.

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1 See Bodlander. Neues Jahrbuch fur Mineral, etc. 1893, II, S 147.
2 Tumin, Ibid page 49-52.

Crust alkali from the First Administrative District Naursum[1]:

Horizon and depth in cm	Color	Total amount of solubles substance	Loss on ignition	Mineral residue	Alkalinity as Na_2CO_3	Cl	SO_3
A (0 to 6)	faint yellow	0.0388	0.0148	0.0240	0.0146	0.1013	0.0178
B_1 (6 to 23)	golden yellow	0.2600	0.0668	0.1932	0.0642	0.0756	0.0201
B_2(23 to 45)	yellowish	0.5880	0.0999	0.4981	0.0408	0.2592	0.0394
C (45 to 79)	almost colorless	1.2872	0.1924	1.0948	0.0350	0.2214	0.4856
C (79 to 97)	colorless	1.1866	0.1174	1.0692	0.0146	0.2349	0.4200

Crust Solonetz from the Second Administrative District of Naursum[2]:

Horizons and depths in cm	Color	Total amount of soluble substance	Loss on ignition	Mineral Residue	Alkalinity as $2(HCO_3)$	Cl	SO_3
A (0 to 6)	golden brown	0.1064	0.0336	0.0728	0.0286	0.0008	0.0130
B_1(6 to 25)	" "	0.4680	0.0756	0.3940	0.0739	0.1262	0.0172
B_2(25 to 60)	faint golden yellow	1.8700	0.1290	1.7420	0.0341	0.2502	0.7570
C (60 to 90)	colorless	2.3180	0.1478	2.1400	0.0556	0.1924	1.0420

If the soil reacts alkaline but contains at the same time along with the soda a considerable percentage of chlorides and sulphates, no Columnar Solonetz will be formed, but a faint development of a crust will be formed instead. An example of such is furnished by a soil from Ssemipalatinsk, an analysis of which is given in the following table[3]:

1 Skalow, Work of the Expeditions for Investigating the Soils of the Regions to be Colonized in Asiatic Russia, Soil Investigations, 1909, part 2, 1910, page 72. (Russian).

2 Lewtschenko, Idem. Soil Investigation, 1908, Part 1, p. 68. (Russian)

3 Abutjkow, Idem. 1909, Part 3, page 67. (Russian)

Unlike the Solonetz, the Solons.

Horizons and depth in cm	Color	Total amount of soluble substance	Loss on ignition	Mineral residue	Alkalinity	Cl	SO_3
A (4 to 16)	dark brown	1.5966	0.1354	1.4612	0.912	0.0276	0.7877
B_1(23 to 28)	golden yellow	0.9771	0.0491	0.9280	0.1882	0.0402	0.3870
B_2(54 to 59)	colorless	0.7822	0.0240	0.7582	0.1382	0.0478	0.3086

On the basis of its character and profile this soil should be grouped with the Solontschak soils, or at least among the transition forms between the Solonetz and Solontschak[1] soils.

The chemical characteristic of the Solonetz soils belong to a certain extent to the Solonetz-like soils. The faintly Solonetz-like soils differ very little in their chemical characteristics from the soils of the zone in which they occur.

Unlike the Solonetz, the Solontschak soils react alkaline as may be seen from the preceding discussion, but at the same time they contain so large a content of chlorides and sulphates in the upper horizons that the formation of humic acid gel and the consequent translocation of the pseudo-solution, as well as the suspended material, from one horizon to another are impossible.

The water extract of the chloride and sulphate bearing Solontschak from the Akmolinsk region, the profile of which was described on pages 207 gave the following results on analysis.

[1] The morphology of the profile of this soil is described by Abutjkow on pages 62-63 of the report referred to above. Horizon A to a thickness of 2 cm forms a thin rather hard crust with an ill-defined finely porous and laminated structure. Other humus horizons are loose soft cloddy or structureless.

Horizon and depth in cm	Residue on drying	Organic matter	Alkalinity as $2(HCO_3)$	SO_3	Cl	Remarks
A (0 to 1)	4.5142	0.0365	0.0204	1.0106	1.3532	Golden yellow extract. Filtered rapidly.
A (1 to 5)	2.0062	0.0160	0.0205	0.2291	0.8500	A little lighter than the preceding. Filtered rapidly.
A_2(18 to 23)	2.2604	0.0084	0.0181	0.2292	0.9687	Much lighter than the preceding. Filtered rapidly.
A_2(40 to 45)	3.1193	0.0070	0.0156	0.5312	1.1358	Almost colorless. Filtered rapidly.

The water extract of the Solontschak soil rich in sulphates and chlorides from the Syr-Darja region, described on pages 207, gave on analysis the following results: (See page 224)

Soft Solontschak soils of this kind are known by the Khirgiz as "Kebir" and the columnar Solontschak as "Schokat"[1]. The softness of the Solontschak soils is seemingly due to the secretion and formation between the soil grains of sodium sulphate, sodium chloride and gypsum.

The descriptions and analytical data already given enable us to explain details of the profile and structure of the Solonetz and Solontschak soils. The laminated structure of the surface Solonetz horizon is explained by the gradual drying out after the saturation to which it is subjected in spring time while its porosity is due as we have already seen to the formation and expansion of CO_2 when $NaHCO_3$ changes to Na_2CO_3. The heavy texture and plasticity of horizon B is due to its high content of translocated "gel" and very fine grained mineral particles. The process by which the columns and prisms are formed is similar to that which forms basalt columns. The latter are formed on cooling, the former on drying. The breaking up of the lower part of the B horizon into many sided and highly angular fragments is due to the presence of considerable amounts of substances which cause coagulation, mainly chlorides and sulphates. The lime carbonate plays apparently an unimportant role.

As to the geography of the Solonetz and Solontschak soils, their formation in flat areas is determined by the accumulation of salts and poor drainage. Salts may accumulate either in the deeper

[1] The Khirgiz use still other terms for alkali soils as for example, "Takyr," "Chak," and "Sor". With the word "Sor" they designate according to Neustrujew (Pedology, 1911, No. 2, p. 39) merely the locality in which the soil is found. "Chak" designates the temporarily excessive moisture of the locality where Solontschak soils occur. "Taky" designates a spot bare of vegetation, hard with a metallic sound under the hoof. It is in part a geological product.

Depth in cm	Residue on drying	Loss on ignition	Mineral residue	R_2O_3	CaO	MgO	K_2O	Na_2O	Alkalinity		SO_3	Cl
									Na_2CO_3	$NaHCO_3$		
The Crust	0.813	0.011	0.802	0.0020	0.0402	0.0013	0.0111	0.2997	0.0015	0.0565	0.430	0.0070
1 to 4	5.369	0.062	5.303	0.0056	0.1126	0.0078	0.0249	2.0938	0.0024	0.0419	2.948	0.0310
10 to 20	1.982	0.095	1.887	0.0020	0.1107	0.0343	0.0291	0.7378	0.0004	0.0259	0.543	0.5810
103 to 110	0.790	0.009	0.780	0.0012	0.0114	0.0079	0.0076	0.3576	0.0015	0.0341	0.334	0.2671
130 to 140	0.378	0.001	0.377	0.0016	0.0049	0.0055	0.0058	0.1887	0.0025	0.0372	0.815	0.1331

horizons or may be brought to the surface by the ground water. In the latter case alkali soils may form on perfectly even surface.[1]

Alkali soils are rarely found in areas well dissected by ravines and hollows, a semi-arid region having good drainage or in a region having soils that are leachy. In such cases the ground water surface lies at considerable depth. Under conditions the opposite of these the alkali soils usually replace the zonal soils in part only, though they may completely replace them. Under normal conditions however the resulting condition is described as a soil complex, that is to say, there is formed a very variable condition in which there will occur zonal soils, faintly Solonetz-like soils, Solonetz-like and Solonetz soils all within a small area[2]. Such soil complexes are especially characteristic of the Brown Earth soil zone.

In concluding the chapter on alkali soils we will give the chemical characteristics of Mountain Carbonate Solontschak soils, the morphology of which has already been described. The following data concern soils, already described, from the upper course of the Koksa river in Jenisseisk.

Depth in cm	Water at 105° C %	Humus %	Loss on ignition %	CO_2 %
3 to 8	7.67	20.33	24.74	...
18 to 23	5.83	9.83	14.10	...
45 to 48	5.37	...	...	7.53
55 to 60	3.59	...	...	9.48

Depth in cm	Color of the extract	Mineral matter	Loss on ignition	Dry substance	Alkalinity as (HCO_3)	Cl	SO_3
3 to 8	strong yellow	0.0416	0.1104	0.1520	0.0480	0.0035	0.0056
8 to 23	faint yellow	0.0310	0.0670	0.0980	0.0504	0.0015	0.0070
50 to 55	very faint yellow	0.0286	0.0110	0,0396	0.0480	0.0002	0.0057

2 (Footnotes on following page.)

Complete Analysis

	Percentage composition of soil dried at 105° C		
	3 to 8 cm	8 to 23 cm	55 to 60 cm
Loss on ignition	25.53	14.22	13.12
SiO_2	47.47	55.21	51.44
Al_2O_3	13.76	15.80	15.28
Fe_2O_3	5.66	6.78	5.60
CaO	3.33	2.79	11.05
MgO	1.08	1.63	0.84
K_2O	1.34	1.31	1.29
Na_2O	1.28	1.43	1.29
P_2O_5	0.27	0.21	0.15
N	0.31	0.21	0.04

When the above analyses are calculated on a carbonate and humus free basis we receive:

SiC_2	63.71	64.67	66.83
Al_2O_3	18.47	18.50	19.84
Fe_2O_3	7.60	7.94	7.27
CaO	4.47	3.25	1.36
MgO	1.44	1.90	1.09
K_2O	1.80	1.53	1.67
Na_2O	1.71	1.67	1.67

[1] Water extracts of horizon B of the alkali soils with structure filter slowly as a rule, as do all strongly alkaline reacting soils and soils whose water extracts "contain no electrolytes." That fact is explained by the influence which an alkaline medium exerts on colloids and suspended matter.

[2] See Neustrujew, Pedologie, 1910, 2.

From the above data it is evident that the mountain carbonate Solontschak soils, in their upper horizons have a very high humus content, in one case amounting to 32.79%. Such quantities however have been found only in the upper 10 to 15 cm of the profile. Below this it decreases although in some samples 7 to 9% of humus was found at a depth of 30 cm. Such a rapid decrease enables us to to distinguish this soil from Tschernosem in which the decrease from the surface horizons downward takes place gradually.

The strong hygroscopicity of these soils corresponds with the high humus content of the upper horizons, in part, in the form of the finest peat-like dust particles which in the samples could not be mechanically separated from the mineral matter. The samples of the humus horizon dried at room temperature often contained 9 to 12% of hygroscopic moisture.

The water extracts give a faint alkaline reaction. The soils are similar therefore to those of the steppes and dry steppes. They contain very little chloride and sulphate, like Tschernosem, but they differ from the latter in the predominance of organic substances in the water extract.

The various horizons are in composition like those of the Tschernosem as may be seen by consulting the analysis given above. In the samples investigated the lower horizons seem to have become richer in silica and alumina than the higher. This should not in reality take place in this soil and it would not seem so were it not that the humus horizons, especially the upper one, are richer in bases, lime in particular, than the lower and this base together with potash apparently hold the humus constituent.

Carbonate accumulations are more important in the lower horizons. At a depth of 45 to 48 cm there is already as much as 17% of carbonates and the amount increases downward. In its occurrence, the soil analyzed, as we have seen, is similar to Tschernosem. We shall see also that in many of its characteristics it approaches in appearance the Chestnut Colored soil phase of the Carbonate Solontschak soils. The following analytical data on these soils have been obtained:

Depth in cm	Water at 105°C %	Humus %	Loss on ignition %	CO_2 %
0 to 5	5.24	10.29	14.55	...
25 to 30	4.20	7.16	13.76	7.51
30 to 33	3.77	...	...	11.48
43 to 46	3.65	...	...	11.71
53 to 58	3.93	...	...	6.83

Depth in cm	Color of the extract	Dry substance	Loss on ignition	Mineral residue	Alkalinity as $(HCO_3)2$	Cl	SO_3
0 to 6	Pale yellow	0.1506	0.0984	0.0522	0.0756	0.0016	0.0081
23 to 30	Very pale yellow	0.0814	0.0444	0.0370	0.0528	0.0004	0.0044
30 to 40	Very pale yellow	0.0914	0.0416	0.0498	0.C552	0.0010	0.0060
51 to 58	Almost colorless	0.1156	0.0316	0.0840	0.0564	0.0030	0.0238

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II. Endodynamomorphic Soils

To this group belong all those soil formations partly of fine earth material and partly of undecomposed rock material whose development has been more strongly influenced by the character of the parent rock than by external conditions. So far as we know the humus carbonate soils, at least those in the forested regions of the temperate zone in Asiatic Russia, Western Europe and North America are the most wide spread. In Poland they are called "Rendzina"[1] or "Borowina".

Since the development of the soil drop on soft chalk or still better on marly rocks proceeds more rapidly than the decomposition, the organic remains decompose slowly on account of the alkalinity of the medium[2]. For this reason humus accumulates in the soil in the form of compounds saturated with bases. The accumulation of humus causes the greater part of these calcareous soils to be dark colored sometimes even black.

This characteristic is very striking since the Rendzina soils lie usually in regions in which the external soil forming forces are not favorable to the accumulation of humus, such as those operating in the Podsol zone.

The crystalline and semi-crystalline limestones do not seem to be able, because of the low solubility of the calcite when compared with that of the lime carbonate in the form of chalk, to form Rendzina. It is a fact at least that no Rendzina is formed in Irkutsk and Jenisseisk where soils are developed, over wide areas, from limestones. Well developed Podsol soils are formed rather than Rendzina.

1 Rendzina, - plastic sticky clay soils.
2 For the literature see Wollny, The Decomposition of Organic matter and the formation of humus, 1887.
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In the first stages of their development the humic carbonate soils are usually marked by skeleton-like characteristics or contain in other words considerable undecomposed rock. On the surface of the soil and in its surface horizon limestone and marl fragments are found and they become more abundant with depth until the transition to the loose and fissured parent rock is reached. In more advanced stages of soil development the percentage of such fragments becomes smaller, the surface horizons are made up entirely of fine earth material and only the deeper horizons are spotted by the presence of rock fragments.

The variety of arrangement and profile may depend upon other factors. If we imagine two regions in which the external soil-forming conditions are the same but in one of which the rock is a hard limestone and the other a loose marl, two kinds of skeleton-like soils will be developed. On the former the soil will be coarser, richer in fragments of parent rock, thinner, because of the slow rate of weathering of the hard rock. On the latter the soil will be finer in grain and thicker because of the more rapid weathering of the loose marl.

In Russia the humic carbonate soils do not occur in large unbroken areas but only as isolated spots and islands. This is easily understood since the whole surface of European Russia is covered with unconsolidated deposits and it is only here and there that limestone or marly rocks are to be seen. The unconsolidated cover is rarely marly. The Rendzina soils form as has already been stated, no continuous area of considerable size though they have a wide distribution. In the State of St. Petersburg, Rendzina is formed on the silurian limestone, in Pskov on devonian, occassionally though on brackish chalk, in Kaluga on cretaceous marl, in Poland on triassic, jurassic, createaceous and post tertiary limestones, and on marl and marly clays. In Saratow they are formed on chalk.

Rendzina occurring outside the Podsol zone is apparently the same as that found in existing or former forested regions for under the influence of steppe conditions limestones and marls are converted into soils which are the same as the normal Tschernosem.

The Rendzina soils are found in Russia, Germany, Sweden and seemingly also in other European states which lie in the Podsol zone.

The Rendzina profile is as follows:

A. A gray to dark gray surface layer, in places almost black, containing more or less fragmental marly material. Occasionally it is free from limestone or marl fragments. Its thickness varies, ranging from 15 to 30 cm.

A_2. Whitish gray, faintly colored with humus, at times brownish also, containing a considerable quantity of fragments of the parent rock, limestone and marl.

C. Mass of parent rock fragments.

The dryer the surface horizon, the grayer its color. In very dry condition it contains a great deal of dust which is blown about by the wind. In Saratow these soils are popularly known as dust soils or ash soils.[1]

The humus lime soils are different from the soils just described. They are developed from brackish lime tuff and contain a considerable quantity of hydrated iron oxide. In such cases all the horizons have a reddish or ochre-brown color since the color of the iron oxide covers that of the humus material.

The chemical characteristics of the Rendzina soils have not been thoroughly investigated. In Russian literature there are no analyses to be found except a few from Poland.

The humus of these soils is less soluble than that of the neighboring Podsols, but more soluble than that of the Tschernosem[2]. The humus content in various lime soils ranges from 1.5 to 7% usually from 3 to 4.

The following table presents the composition according to Malewski[3] of Rendzina from the vicinity of Menzmersh in Lublin. It shows the composition of the fine earth of each horizon which passed through the Knop sieve No. 5:

The following substances and amounts were dissolved in cold HCl with spec. gr. 1.12.

	A	B	C
Water at 105°C.	2.637	2.489	2.014
$CaCO_3$	46.69	60.58	69.66
$MgCO_3$	.52	.24	.09
Al_2O_3	1.26	.83	.25
Fe_2O_3	.69	.59	.47
SiO_2	.006	.003	.003

The insoluble residue after ignition contained the following:

	A	B	C
SiO_2	82.10	78.65	81.75
Al_2O_3	10.81	15.12	13.58
Fe_2O_3	1.59	2.38	2.24
CaO	5.13	4.14	1.12
MgO	1.34	0.21	0.11

1 Dimo. Pedologie, 1904, No. 2. The peasants here call ashes "pepel" and the dry Rendzina soils are sometimes ash-colored. This color is striking when found in the Tschernosem zone since the prevailing soil color here is black.

2 Lesniewski, Report of the institute of Nowo-Alexandria, 10 (Russian).

3 Malewski. Ibid. 1876, 1877 (Russian).

In Germany a thorough petrographic, physico-mechanical and chemical investigation of the humus lime soils has been made by Luedecke.[1] His investigations covered the soils in the vicinity of Goettingen where they lie on the various members of the Muschelkalk. His results are as follows: (See page 232.)

In the section devoted to soil classification we have indicated that Rendzina soils are mere temporary transition forms, like all endodynamomorphic soils, and may change to zonal soils when the product of weathering has lost the specific characteristics which are due to derivation from a parent rock with strong characteristics. An example of the gradual change of a Rendzina soil has been given from the vicinity of Cholm in Lublin. A similar example was analyzed by Councler[2] who studied its composition on the basis of its horizons which he described as follows:

1. Uniformly colored humus horizon 2 - 4 cm.
2. Gray, or blackish brown loamy horizon 23 - 30 cm.
3. Yellowish clay. 5 - 16 cm.
4. Parent rock.

	1.	2.	3.	4.
H_2O	7.59	4.26	8.70	0.21
CO_2	0.14	0.56	1.11	41.74
SiO_2	63.57	67.74	54.13	2.06
Al_2O_3	9.83	12.13	17.60	0.90
Fe_2O_3	3.82	2.90	6.53	0.51
CaO	1.14	1.16	1.16	52.98
MgO	0.94	0.99	0.83	0.76
K_2O	2.32	2.64	2.65	0.39
Na_2O	0.66	1.09	0.93	0.30
P_2O_5	0.21	0.22	0.20	0.03

[1] Zeitschrift fur Naturwissenschaft, 65, Heft. 4 and 5.
[2] Councler, Zeitschrift fur Forst und Jagdwesens, 1883, 16.

Mechanical Composition

Locality	Percentage comp. of whole soil — Diameter of particles: More than 10 mm.	10 to 4 mm.	4 to 2 mm.	Less than 2 mm.	Percentage composition of fine earth — Diameter of particles in mm.: 1 to 2	0.5 to 1.0	.2 to .6	.1 to .2	.05 to .01	.01 to .05	Less than 0.01
Dransfeld	50.2	4.7	0.8	44.3	4.5	2.2	7.9	5.4	9.2	11.6	57.8
"	12.7	13.7	4.0	69.6	2.9	3.3	1.7	3.9	5.9	23.2	58.6
Deppoldhausen	0.1	0.7	0.2	99.0	0.5	0.7	0.7	1.7	12.1	41.6	43.2
"	0.0	0.1	0.2	99.9	0.1	0.5	0.8	4.0	19.3	41.2	3.43
Rosdorf (soil overlying tuff)	1.6	2.5	0.7	95.2	4.2	4.9	3.1	4.7	19.9	41.2	21.4

Chemical Composition

Locality	Solventt	Water in the fine earth	Insoluble residue	Loss on ignition	SiO_2 dissolved in acid	SiO_2 dissolved in soda solution	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	Na_2O	CO_2	P_2O_5	SO_3	Total	N
Rohringenn		3.93	50.93	5.09	0.08	7.61	3.89		11.72	5.57	0.25	0.2	14.5	0.17	0.34	100.3	0.15
"	HCl	3.16	61.88	3.37	0.14	12.01	8.3	6.55	2.91	0.82	0.46	0.12	2.49	0.11	0.12	99.73	0.17
Deppold-hausen		3.20	70.34	3.03	0.12	11.96	3.95	8.37	0.53	0.46	0.56	0.12	0.04	0.18	0.15	99.81	...

Horizons 1 and 2 are similar in their chemical composition to the Podsols, since both have a lower percentage of sesquioxides than horizon 3. They are richer in silica also.

Other soils of the endodynamomorphic group have been investigated very little. How the soil processes are influenced by the great number of chemical compounds present in the parent rocks, such as $MgCO_3$, iron oxide, gypsum, anhydrite, etc. is almost wholly unknown.

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